



University of **HUDDERSFIELD**

University of Huddersfield Repository

Denton, Paul

Business Strategy Driven IT Systems For Engineer-To-Order and Make-To-Order Manufacturing Enterprises

Original Citation

Denton, Paul (2002) Business Strategy Driven IT Systems For Engineer-To-Order and Make-To-Order Manufacturing Enterprises. Doctoral thesis, Loughborough University.

This version is available at <http://eprints.hud.ac.uk/id/eprint/4417/>

The University Repository is a digital collection of the research output of the University, available on Open Access. Copyright and Moral Rights for the items on this site are retained by the individual author and/or other copyright owners. Users may access full items free of charge; copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational or not-for-profit purposes without prior permission or charge, provided:

- The authors, title and full bibliographic details is credited in any copy;
- A hyperlink and/or URL is included for the original metadata page; and
- The content is not changed in any way.

For more information, including our policy and submission procedure, please contact the Repository Team at: E.mailbox@hud.ac.uk.

<http://eprints.hud.ac.uk/>

(Non-Complete Document: Full Text Only, Excluding Index and Appendices)

**Business Strategy Driven IT Systems
For
Engineer-To-Order and Make-To-Order
Manufacturing Enterprises**

By

Paul David Denton

A Doctoral Thesis

Submitted in partial fulfillment of the requirements
for the award of

Doctor of Philosophy of Loughborough University

October 2002

© by Paul David Denton, Loughborough University 2002.

ABSTRACT

This thesis reports research into the specification and implementation of an Information Technology (IT) Route Map. The purpose of the Route Map is to enable rapid design and deployment of IT solutions capable of semi-automating business processes in a manufacturing enterprise. The Map helps structure transition processes involved in “identification of key business strategies and design of business processes” and “choice of enterprise systems and supporting implementation techniques”. Common limitations of current Enterprise Resource Planning (ERP) systems are observed and incorporated as Route Map implications and constraints.

Scope of investigation is targeted at Small to Medium Sized Enterprises (SMEs) that employ Engineer-To-Order (ETO) and Make-To-Order (MTO) business processes. However, a feature of the Route Map is that it takes into account contemporary business concerns related to “globalisation”, “mergers and acquisitions” and “typical resource constraint problems of SMEs”.

In the course of the research a “Business Strategy Driven IT System Concept” was conceived and examined. The main purpose of this concept is to promote the development of agile and innovative business activity in SMEs. The Road Map encourages strategy driven solutions to be (a) specified based on the use of emerging enterprise engineering theories and (b) implemented and changed using component-based systems design and composition techniques.

Part-evaluation of the applicability and capabilities of the Road Map has been carried out by conducting industrial survey and case study work. This assesses requirements of real industrial problems and solutions. The evaluation work has also been enabled by conducting a pilot implementation of the thesis concepts at the premises of a partner SME.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years, manufacturing enterprises have placed direct emphasis on globalisation as a means of achieving competitive success in the contemporary performance measures of quality, speed and price. The use of Information Technology (IT), Business Process Re-engineering (BPR), together with Mergers and Acquisitions (M&A), can be seen as a basis for achieving this end [1] [2] [3] [4] [5]. The capabilities which manufacturing enterprises need to acquire in this situation include agility and innovation. In this thesis, Vernadat's definition of agility will be adopted, namely a capacity to adapt quickly in reaction to the changing business environment [3], while Denton and Hodgson's definition of innovation will be adopted, i.e. the capacity to renew and update products and processes quickly [6]. The adopted use of commercial Enterprise Resource Planning (ERP) systems can facilitate some of the above capabilities. However, deployments of these all-encompassing business management applications have fallen short in delivering all of the various promises they make and may even place constraints on change [7] [8].

Whilst one set of manufacturing enterprises have much improved their front-end customer-centred systems, others have spent tremendous energy on optimising back-end production planning and control. However, few have focussed upon developing an effective integrated, end-to-end solution targeted towards realising the business strategy of the enterprise. Therefore, it can be far too easy for businesses to continually over promise products and services, and subsequently lose money trying to fulfil the commitments made. Ultimately, both parties lose out.

The problem of failing to reconcile strategic imperatives of the enterprise with the requirements and implemented operation of its technological and business process systems has received a considerable amount of interest from both the academic and industrial communities over the last 10 years [9] [10] [11] [12]. A focus of these interests has been on large, nationally focussed organisations that operate in relatively stable business environments. For Small to Medium Sized Enterprises (SMEs), which deploy complex, globally focussed, Engineer-To-Order (ETO) and Make-To-Order

(MTO) production methodologies, problems of constructing effective computer systems with limited resource are more troublesome and potentially solutions can be relatively short lived [6] [13]. Production can more easily be optimised when there is environmental stability over a reasonably long timeframe. In this type of environment it is easier to predict new requirements and implement changes to systems. The requirement of reducing complexity and aiming to develop a mass customisation capability, are important keys. The ability to offer ways of differentiating products and charging a premium price by better serving customer needs is at the heart of most of enterprise endeavours. Within such a context, the adoption of contemporary ERP systems by SMEs poses many practical, financial and organisational problems. These, often volatile, enterprises at the lower end of the corporate scale, have resource constraints in terms of technology, skill, finance and business processes that deny them access to the, perceived, fast track approach to competitive advantage and sustained success. Typically, standard off-the-shelf ERP systems do not provide the degree of fit that the enterprise requires to support its commercial goals [14] [15] [16].

The research presented here aims to bridge the gap between business need and system effectiveness, re-evaluating the requirements for modern day, enterprise systems architecture and functionality. A prime focus centred is on the creation of an IT Route Map for the development and deployment of such systems, where particular attention is paid to SME needs. The IT Route Map consists three sections, namely a 'Business Model Template', 'Systems Architecture' and an 'Implementation Framework'. The intention of the 'Business Model Template' is to act as a generic business model for SMEs operating in ETO and MTO environments. It presents an industry overview or characterisation in terms of key business processes and critical performance measures related to the target environment. The 'Systems Architecture' provides a foundation upon which the development of an enterprise's computer systems should be based. It lists the key elements that should comprise newly designed systems, with special regard to reducing impacts arising from limitations of current ERP systems. The 'Implementation Framework' then will draw together the first two elements of the IT Route Map, to provide a comprehensive methodology for implementing such systems, driving IT systems development directly from business strategy, rather than as a consequence of business survival. Once defined the IT Route

Map is implemented and validated with reference to an industrial case study and its requirements, data and practical technical solutions.

1.2 The Structure of the Thesis

The thesis is divided into the five main sections as detailed in Figure 1.1 Section one is comprised of five chapters that introduce the subject matter, review current thinking, and comment upon an industrial survey and case studies. Chapter 1 introduces this research contribution and outlines a pictorial representation of the thesis structure and background. Chapter 2 represents a survey of current literature pertinent to the research aims and content of this thesis. The content of this review chapter is organised under four headings, namely: Business Arena, Management Concepts, Manufacturing Techniques and Philosophies and an IT Perspective. All of these elements consider the contemporary research and their individual implications upon the proposal and implementation of an IT Route Map for implementing Business Strategy Driven IT Systems. An overview of review findings is presented in Figure 1.2, which shows a Literature Framework.

The principle objectives, scope and rationale of the research, together with an introduction, to Business Strategy Driven IT Systems is presented in Chapter 3. Chapter 4 presents the findings of an Industrial Survey related to the modern day implementation of ERP type systems within SMEs and Chapter 5 describes investigative findings from three case study enterprises. Having reviewed the relevant literature, considered empirical results of a survey, and investigated results from supporting industrial case studies (documented in the appendix) section two comprises Chapters 6 and 7. Chapter 6 defines the requirements for a new approach to tackle the problem of receiving strategic benefit from the implementation of enterprise wide business systems. The notion of Business Strategy Driven IT Systems is explored in Chapter 7, describing its components and applicability to the modern day manufacturing environment. The concept of an IT Route Map is then specified.

Section three, comprises Chapters 8 to 11. It describes constituent parts of the IT Route Map, with a chapter devoted to each major element, the Business Model Template, Systems Architecture and the Implementation Framework. Chapters 8, 9 and 10, constitute the core new work, and the philosophical argument of this thesis.

Chapter 11 seeks to begin to evaluate aspects of this novel thinking with respect to a real-life industrial situation and thereby endeavours to underpin and validate the rational for the work and its contribution to knowledge. The fourth section deals with research conclusions consists of two chapters. Chapter 12 discusses a broad spectrum of research and theoretical issues which range from the conceptualisation of Business Strategy Driven IT Systems, to the realisation of the IT Route Map as an integrated implementation tool. Chapter 13, of the thesis then affords a list of possible further research avenues that can be investigated for the continuation and more complete evaluation and industrial testing of this research effort. The final thesis section is made up of the appendices, industrial case studies and the author's conference publications.

The author's work has been influenced by earlier research investigations whilst participating as an Associate in a Teaching Company Directorate Scheme at a specialist manufacturing company, and more recently whilst carrying out IT management roles within two multi-national companies. These experiences provide evidence in support of the notion that there is a urgent need to bridge a gap in current industry thinking and best practice when engineering and developing large scale IT systems. The proposed concept is that emerging academic theory on business process engineering and software components can be coherently applied to address key aspects of this common industry need.

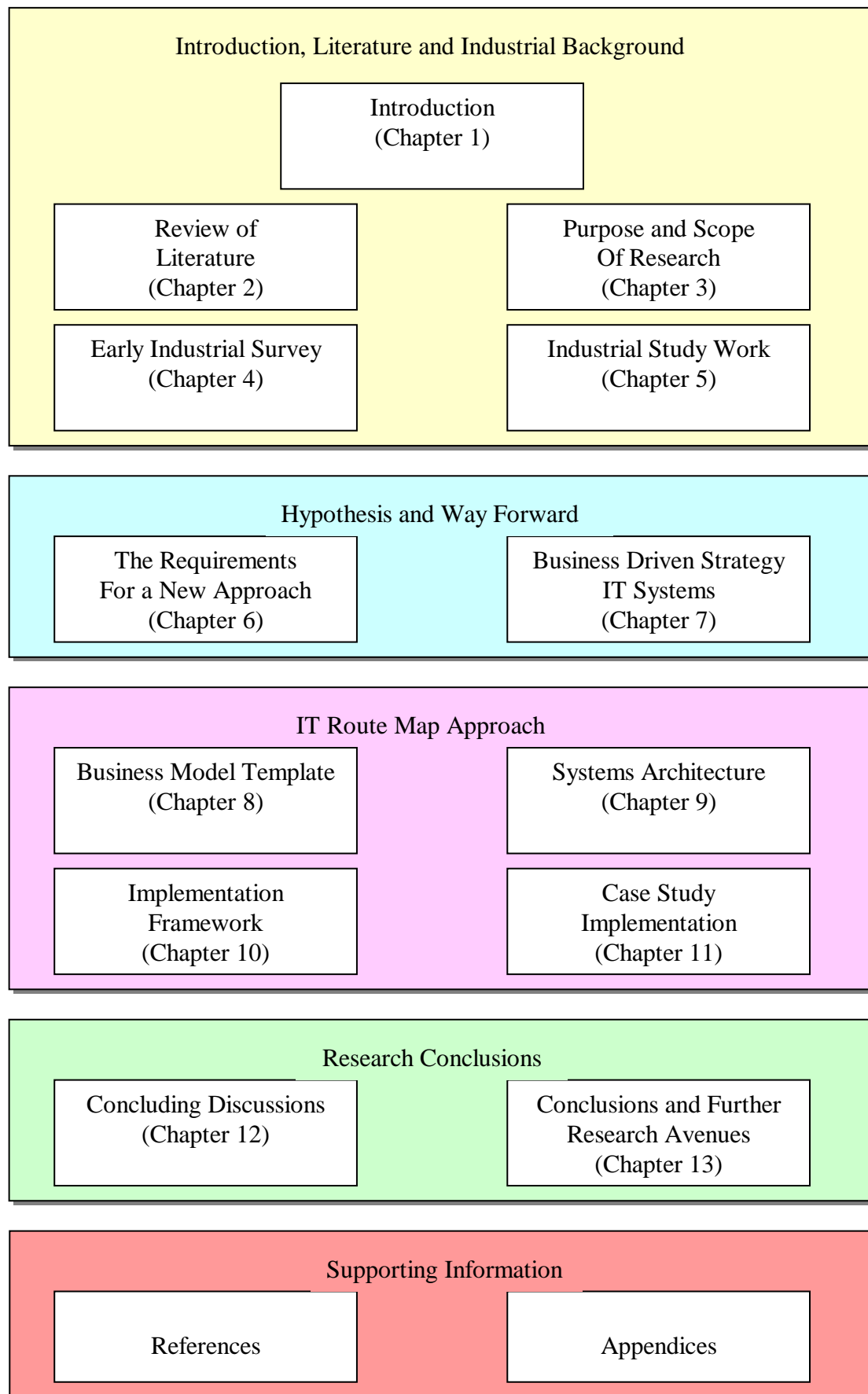


Figure 1.1: *Indicative Sections of this Thesis*

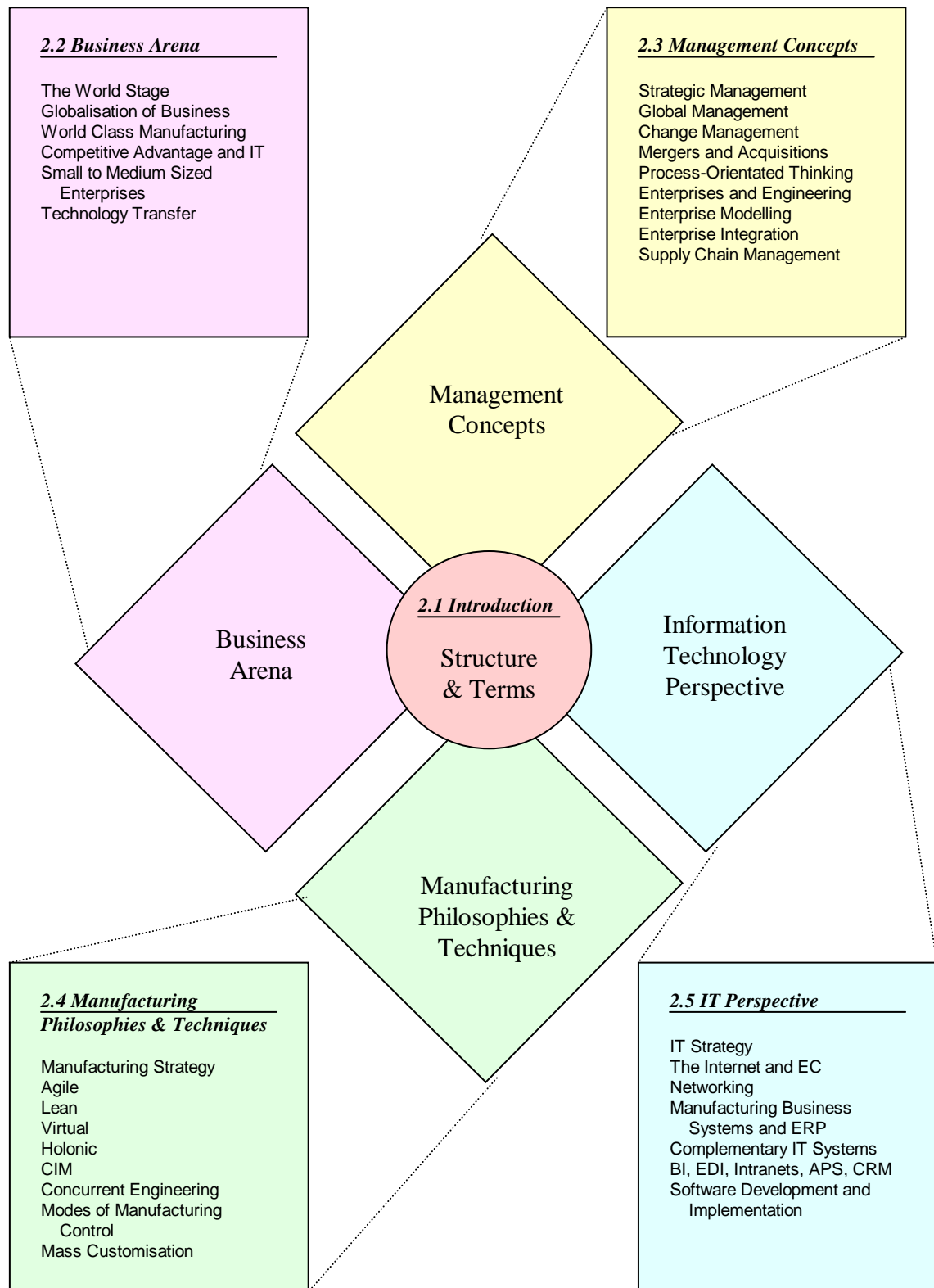


Figure 1.2: Literature Framework

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

This literature survey aims to provide an overview of how modern research concepts and themes have influenced the deployment of enterprise wide, advanced business systems in small to medium sized manufacturing companies to support business development and globalisation. This chapter comprises the following four sections:

- ❑ Business Arena.
- ❑ Management Concepts.
- ❑ Manufacturing Philosophies and Techniques.
- ❑ IT Perspective.

These main sections are then sub-divided into complementary subject areas, that each discuss and comment upon key research aspects that are material to the foundation of this thesis. To provide a better understanding of the terms and concepts frequently used in this work, with particular reference to enterprises, the following basic definitions can be used.

Enterprise: An enterprise is an socio-economic organisation created to produce products or to procure services and to make profit [3].

Enterprise Engineering: To define, structure, design and implement enterprise operations as interconnected networks of business processes, which comprise all their related business knowledge, operational information, resources and organisational relations [3].

Enterprise Integration: To provide activity co-ordination, delivering information and appropriate resource at the right place and the right time and thereby enable communication between people, machines and computers and their efficient interconnection and co-operation [17].

Enterprise Resource Planning (ERP): In concept is a wholly integrated set of business applications that assist everyone in an enterprise to plan, monitor and control their part of the business [18].

Enterprise Model: An enterprise model is a representation of a perception of an enterprise. Any enterprise model can be composed of several sub-models including (but not limited to) process models, data models, resource models and organisational models [3].

Enterprise Modelling: Enterprise modelling is the process of building models of whole or parts of an enterprise (e.g. process models, data models, resource models, etc) from knowledge about the enterprise, previous models, and/or reference models [19].

Enterprise Activity: An enterprise activity (or simple activity) is a set of partially ordered basic operations executed to perform things to be done within an enterprise. Activities are performed by functional entities of the enterprise and transform an input state into an output state [3].

Functional Entity: A functional entity is any active resource inside or outside an enterprise capable of executing basic functional operations of an activity and playing a given role in the course of a process. A similar term used in Artificial Intelligence is an agent [3].

Small to Medium Sized Enterprise (SME): A designation of enterprise that employs less than 500 people [20]. In respect of this research work, the SME group includes enterprises which are either, a consistent part of a larger organisation (i.e. a large corporate organisation is made up of several autonomous SMEs that operate with a limited degree of integration) or SMEs which exist as independent entities.

Computer Integrated Manufacture (CIM): Is concerned with providing computer assistance, control and high level integrated automation at all levels of manufacturing (and other) industries, by linking islands of automation into a distributed processing system [21].

Business: Is an entity, which aims to transform inputs to outputs in a way, which increases their value [22].

Business Process: A set of logically related tasks performed to achieve a defined business outcome [23].

Business Process Re-engineering (BPR): Fundamentally re-thinking and radical design of business processes to achieve dramatic improvement in critical contemporary measures of performance, such as cost, quality, service and speed [1].

Engineer-To-Order (ETO) Product: A product, that requires engineering design, a Bill of Materials (BOM) and routing work before manufacturing can be completed. Such products typically require master scheduling of 'average' or 'typical' items or expected activities and capacities, with many individual components being identified only after preliminary design work is complete [24].

Make-To-Order (MTO) Product: A product, which is finished after the receipt of a customer order. Frequently long lead-time components are planned prior to the customer order arriving to

reduce the delivery time to the customer. Where options or other sub-assemblies are stocked prior to customer orders arriving the term, Assemble-To-Order (ATO) is frequently used [24].

2.2 Business Arena

Today's global business environment can be characterised by intensified competition, resulting from market saturation and increasing demand for customer-orientated production [10]. Technological innovations, both in design and manufacturing systems have had a significant influence upon the competitive environment. More recently, it has been increasingly realised that manufacturing businesses are moving towards global operations. These global operations seek to have a presence in most of the world's major regions [4]. To meet the requirements of modern markets, new paths must be forged in management concepts, organisational methods, IT and manufacturing technology. Previously the introduction of mass production combined with a greater division and simplification of labour heralded a new manufacturing era. Nowadays a new stage has been entered into, with barriers to market entry being removed, allowing SMEs to flourish. This has been facilitated by rapid advances in digital computing and matured by the advent of the Internet.

2.2.1 The World Stage

Warnecke [25] states that in recent years have showed the manufacturing community at large, to be deeply troubled and is in desperate need of a new direction to take. The most dramatic examples of these are the break up of the former Soviet Union, the boom and bust of the world economy, environmental sustainability concerns and the growth in the use of the Internet. The perceived lack of direction may be attributed to the ever growing variety of manufacturing systems available and the increased complexity that new technologies inevitably bring. Methodologies such as lean production, together with systems such as ERP and electronic commerce have been recently in vogue together with much emphasis being placed on organisational change and computer integration [8]. The problem is born of the uncertainties, which are present in the world political stage and the dynamics of global economics. Delargy [26] comments, 'The so-called new economy is distinguished by the importance of intangible assets, particular knowledge and information, but also the product service that can be created, stored or transferred in digital format'.

Manufacturing today, can be seen as a prime driving force towards a nation's wealth and success. Within the last century the discipline of manufacturing has had a tremendous impact on the social and economic development of many countries, in particular Great Britain, Germany, the United States of America and Japan.

According to Rembold et al [27], manufacturing creates between 60 and 80% of the wealth of the major industrialised countries. It is for this reason that most of these countries have numerous, government and industry, supported programmes to produce higher manufacturing productivity. The experience of the UK manufacturing sector in recent decades has in some respects resembled that elsewhere, with a falling share of Gross Domestic Product (GDP), Table 2.1.

CURRENT PRICES					
	% Shares			Average %	Change Pa
	1970	1980	1990	1970-80	1980-90
UK	28.8	23.2	18.9	-2.1	-2.6
France	29.9	24.2	21.0	-2.1	-1.4
Germany	38.4	32.8	31.2	-1.6	-0.5
Italy	27.1	27.8	22.4	0.3	-2.2
Japan	36.0	29.2	28.9	-2.1	-0.1

Table 2.1: *Shares of Manufacturing in GDP [28].*

In other respects the UK manufacturing sector has been distinctive, for example in its virtually static output over two decades. Levy and Nonbehel [29] comment that there are three reasons for regarding manufacturing as very important to the UK.

- (i) It provides over 60% of UK exports, compared with, under 25% in the case of services [29].
- (ii) A significant proportion of the service sector depends on manufacturing [29].
- (iii) It is extremely improbable that service industries could substitute for a substantial part of UK manufacturing [29].

In the UK today, there are approximately 130,000 manufacturing companies, with a total of 4 million full-time employees. Almost 30% of UK manufactured output is exported and this accounts for 60% of all UK exports. Manufacturing represents 23% of GDP and directly employs almost 20% of the entire workforce. Around one quarter

of all UK-based manufacturing is foreign owned [30]. The UK Technology Foresight Programme has suggested six generic drivers of change for UK-Based manufacturing towards 2015. These topics can be associated with specific market and technology developments to gain competitive advantage.

1. Internationalisation: The influence of overseas markets and enterprises.
2. Changing customer requirements and sales-and-service networks.
3. Competitiveness through agility, focus and partnerships.
4. People skills, motivation, leadership, teamwork, learning, knowledge and innovation.
5. Responses to environmental concerns and regulation.
6. Influence of IT and communications.

The pressure of this race for competitive advantage has lead to complacency and fear, which manifest themselves as a smoke screen for doing nothing. New technologies, manufacturing systems and techniques come and go, as is shown throughout history, the big questions are "Which ones do we chose?". The answer to that question is that nobody really knows. The Japanese term for a continuous improvement process, 'Kaizen', can be used to provide an answer in part.

KAIZEN : *constant and gradual improvements in all
areas and on all levels.*

- doing little things better.
- always being better tomorrow than today.
- setting and maintaining constantly higher standards.
- regarding everybody as a customer.

Masaaki Imai

2.2.2 Globalisation of Business

Srinivas [31] proposes, 'Business has become the dominant metaphor of our times'. This combined with the value of international competition, are ranking high in the list of issues confronting enterprises today. The world can be seen to be a massive, border-

less economy [32]. Economics, not politics are defining the landscape on which all else must operate. A changing world order is now reflected with the breaking down of market barriers across the globe. Previously competition took place on a playing field defined largely by and contained within the political borders of nations. Economics now is the mainstay that we all, including governments and institutions, must follow. It has been shown that the global capital market dominates, countries alone cannot control, markets, exchange rates or protect their currencies [26].

The increasing importance of global competition has been recognised by both the academic and business communities [33] [34] [35]. The subject though is far from new. Considerable research into comparative advantage has investigated the many implications of the various theoretical models of international trade and organisations [36]. This work is solidly founded on an enterprise's ability and scope to exploit its knowledge, developed in its own locality, in other markets at minimum cost, thereby combating the unavoidable additional costs of doing business in a foreign country. Also, there is related work on the problems in gaining entry into new foreign markets [37] and how enterprises should compete abroad supported by rigorous management principles [38]. This has recently been turned upon its head by the potential of electronic commerce. Datamonitor has predicted that the market size for e-business services in 2004, will be \$1800 million for manufacturing, significantly larger than that for financial services (\$1360 million), and retail (\$1360 million) [26].

Porter [39] comments that the knowledge we hold of global competition does not address the most pressing questions facing the business community today. Research and practice frameworks for global trade have at best given an incomplete view of how to develop a global strategy and how such a strategy should be selected, but more is needed. Porter states, 'We know more about the problems of becoming a multinational than about strategies for managing an established multinational'.

The task of achieving the globalisation of a given business seems to be a multi-stage process [31]. There are many phases that a traditional organisation must go through before it can be truly called a global concern. The stages may be designated as domestic, export, international / multinational and global. According to Rhinesmith [40], the following scenario describes this development procedure.

'When an export company establishes its manufacturing or distribution facilities abroad it becomes *international*. It achieves cost advantages and all significant decisions will continue to be made at home. When a company creates miniatures of itself in other countries, staffed largely by nationals and gives it a wide degree of autonomy it can be called *multinational*. The truly *global* organisation goes further. It relocates some functions on a global scale to places other than headquarters. A multi-centred organisation emerges that can serve all parts of the firm anywhere in the world. For example Phillips moved its long-range technology development centre from the US to the Far East to take advantage of longer-term thinking and reward patterns. Thus in the global organisation, the strategy and structure is without national boundaries. The heart of the global organisation is its culture, its vision, mission, policies, procedures, systems and practices.'

Therefore the process of becoming a true global concern is difficult and complex, at each phase new strategies and organisational structures are required to facilitate the changes. The direction towards becoming global needs a dedicated and determined leadership, what Srinivas [31] calls a 'global mindset'. This approach uses a set of managers with an ability to look at the world from a broader perspective, they have a tendency to be open to themselves and to others by rethinking boundaries and changing their behaviour.

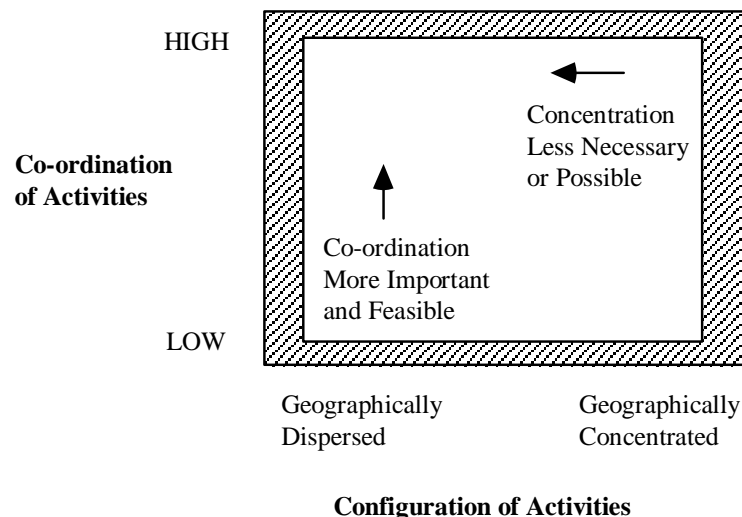


Figure 2.1: *Future Trends in International Competition* [39].

One of most important factor to appreciate is the co-ordination dimension. The advantages that IT can bring to business in term of supporting and facilitating global manufacturing are without parallel. It is shown, Figure 2.1, that the configuration and

concentration of activities are the future imperatives of global strategy. The co-ordination of activities is rising due to the need to support the customer's requirements and offset greater manufacturing dispersion. This is being facilitated by the use of modern technology.

Thus the initial strategies of export and concentration are giving way to more complex global methodologies involving the multiple use of electronic commerce and the Internet, networked overseas plants, world-wide procurement policies and co-ordinated research and design programmes [41]. The task of achieving a global manufacturing capability can be viewed as a problem of co-ordination. The likely successors in this game of international competition are those who can seek out competitive advantages from global co-ordination and configuration anywhere in the value chain and overcome the organisational barriers to exploiting them.

The effective utilisation of new tools such as ERP and the Internet can be seen as some of the most important factors in succeeding in this endeavour. A global strategy is more than just the sum of individual countries' strategy it requires specific investment efforts to develop human resources, to build assets and competencies. It implies a complete transformation of management culture and practices. A strategic framework for the formulation of international development strategies is proposed by Lasserre [42] and is organised around four types of question, Figure 2.2. This work provides a useful strategic foundation and has subsequently been developed and used to underpin a globalisation project in a real-life industrial situation [4].

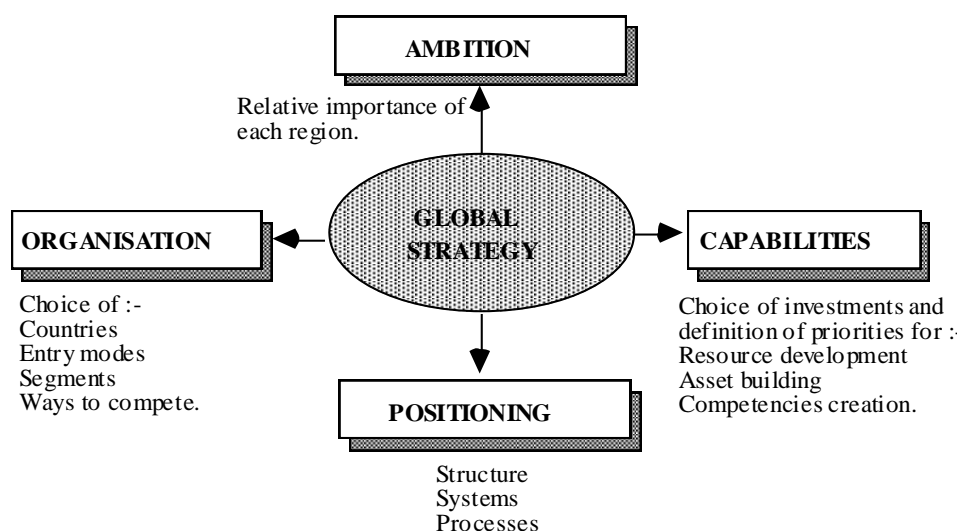


Figure 2.2: *Strategic Framework [42].*

1. What ambitions do we have for each region?

An ambition is what the enterprise wants to achieve both qualitatively (mission, vision) and quantitatively (specific market and finance related objectives) during a strategic time horizon. For global manufacturing the definition of strategic ambition consists of determining the expected future relative importance of each region in the enterprise's portfolio as compared to its existing one.

2. How do we position the enterprise?

Positioning is the selection of the business or market segments in which the enterprise wants to compete and the type of competition profile it wants to adopt. In the global market place, positioning consists of selecting the various countries in which the enterprise wants to operate, in which form and on what basis.

3. What kind of, capabilities need to be created?

Creating global capabilities calls for three basic forms of strategic investment:

- a) Investing in access to external resources - how to access raw materials or components, human resources, financing, information, various types of external support (lobbying, contracts, etc).
- b) Investing in assets - product development, plants, equipment, distribution networks, information systems, logistics, brand names and reputation.
- c) Investing in competencies - what kinds of high technological and managerial know how are required to compete in each region.

4. How do we organise each region?

Organisation covers not only the formal structure, but also the various processes and systems which govern the distribution of power; the rules and procedures; the internal communications; the evaluation and rewards; the co-ordination mechanisms and the management of a 'global culture' which fits with the requirements of each region.

2.2.2.1 Global Market Place Assessment

The strategic importance of each region for the enterprise is determined by a combination of three factors: the importance of each region as a market; the importance of the region as a resource base; and the importance of the region as a source of learning. The issue of global trading has already been identified for the long-

term success of most enterprises [43]. The costs associated with moving towards globalisation are key, Table 2.2.

<i>COSTS</i>	<i>BENEFITS</i>
<i>1. Management</i>	
a proportion of senior management time devoted to project	d acquiring experience of operating in different economies
b proportion of head office staff time (including planning, personnel, R&D)	e making use of spare management capacity and the availability of skilled advice
c costs of administering exports	f greater payback for research
<i>2. Production</i>	
g interest on fixed and current assets used for export	k materials
h design	l labour (wages, benefits, training and employment costs)
i depreciation	m balancing figure for spare capacity
j running costs	
<i>3. Marketing</i>	
p market research and competition research (assessing and allowing for the reactions of competitors)	facilities abroad
q promotion and selling	u exchange losses (+/-hedging costs or gains)
r distribution (transport, insurance, warehousing frontier charges, taxes, tariffs, interest on working capital)	v or gains)
s fees for agents, distributors and foreign salesmen	w income from sales
t costs of offices, warehouses and others	x income from sale of spares and servicing
	y acquiring of goodwill
	z preventing competition
	exchange gains(+/-hedging gains or losses)
INCOME = [v-(p+q+r)]+[x]+[w-t]-[g+h+i+j+k+l-m]-[(a+b+c)-(d+e+f)]+/- [z-u]	

Table 2.2: *Formula for Trading Costs and Benefits [44].*

2.2.2.2 Positioning in the Global Market Place

An enterprise's, global ambitions determine the scope and intensity of its future business operations in each region. This strategy must be concretely reflected in a choice of products and markets. The enterprise must also differentiate itself from its competitors both in a manner in which it chooses to establish a regional presence and in the way it carries out its competitive actions. This set of choices is referred to as 'positioning' and consists of 5 elements:

1. Determining whether the enterprise is interested in accessing resources, or markets or both [41].

2. Deciding on the countries which it wants to operate [41].
3. Deciding on entry mode, whether it will go it alone via wholly owned subsidiaries, or in partnerships such as joint ventures, licensing and franchising arrangements [41].
4. Defining the types of activities it plans to establish, the types of segments in which it wants to compete and a competitive approach which will differentiate it from its competitors [41].
5. Deciding to integrate activities regionally, strategically, or country by country [41].

The enterprise should consider an appropriate mix of market versus resource strategies, as it may not have the inherent potential to subdivide its business processes, such as marketing, research and design, sourcing and production; and move them between countries [39]. In the case of strategic orientation based on access to resources, the enterprise should concentrate its activities in the countries, which have the cheapest or best sources of supply. Whereas with a market based strategy, the enterprise should set up local marketing and sometimes manufacturing activities, either wholly owned or with local partners [36].

The strategic decision making process can lead to three typical approaches for global trade: exporting, knowledge sales and investment. Most enterprises consider the options in that order and only usually enter foreign markets through investment when they have developed valuable knowledge of the country first [44]. However, to experienced enterprises, all the options are always available and the choice depends on the circumstances of the individual market and the amount of capital or management support an enterprise desires to place in that market. The full range of options available can be seen in Figure 2.3.

EXPORT	Direct export	
	Use of exporting company	<i>with equity</i>
	Use of importers, agents or distributors	<i>without equity</i>
	Other export arrangements	<i>with servicing</i>
KNOWLEDGE	Licensing	<i>with equity</i>
	Franchising	<i>without equity</i>
	Contracts	
INVESTMENT	Selling subsidiary	<i>100% equity</i>
	Joint venture	<i>majority holding</i>
	Manufacturing subsidiary	<i>50-50 holding</i>
	Minority holding	

Figure 2.3: Typical International Strategies, [41].

2.2.2.3 Creating Global Capabilities

The most critical part of any strategy process comes when the enterprise's ambition is confronted with the required investments needed to transform it into reality. In the global market place it is not so much the quantitative aspect of the investment effort, but the qualitative aspect which is important [44]. The diversity of enterprise cultures across the globe, the tenacity of certain cultural traditions and ways of doing business make this qualitative dimension both more complex and more crucial to the success of the enterprise's ventures in each region [45]. The following problems have been encountered when enterprises try to develop globally:

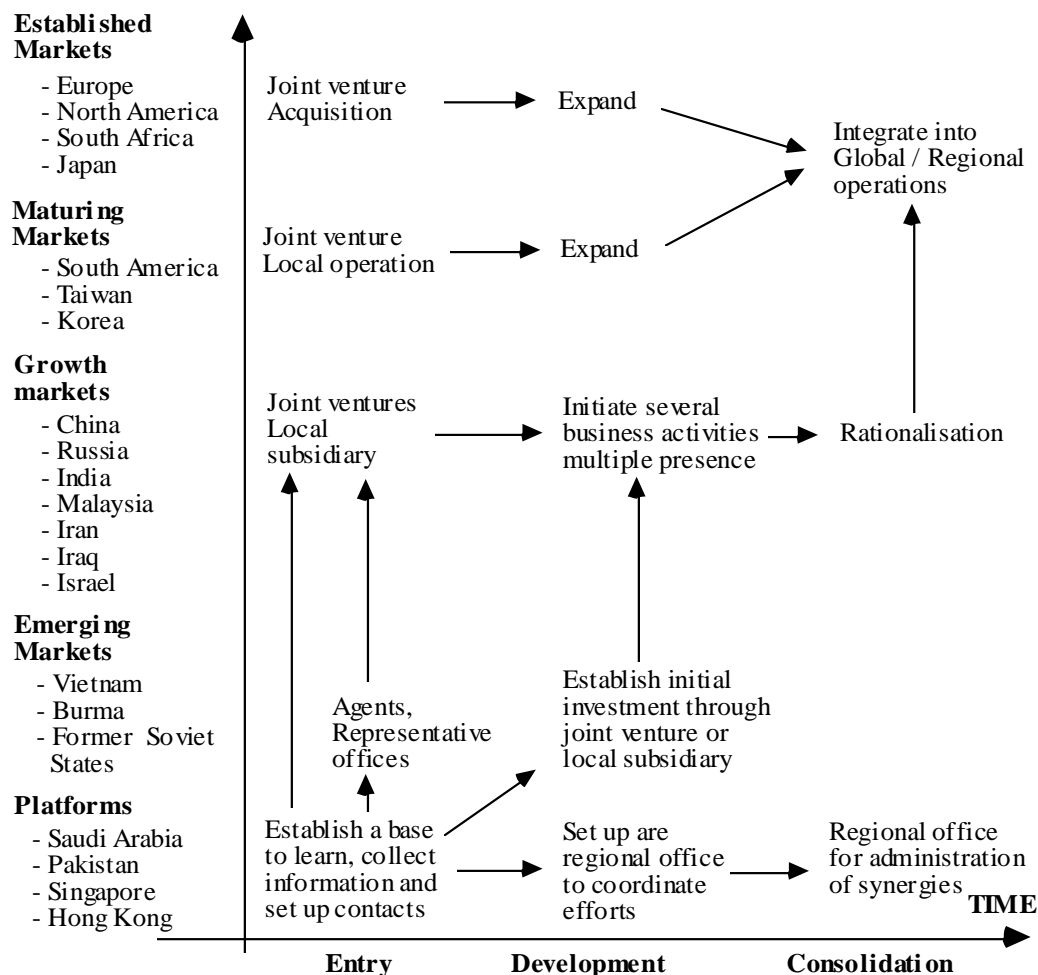


Figure 2.4: Entry Modes and Market Development [4].

- Marketing and strategic information are difficult to obtain either because it is sparse or because it is unreliable. Consequently, forecasting market demand, assessing competitors and finding local partners is more difficult [42].

- Building contacts and relationships, is a pre-requisite of any strategic developments, but relationship building and networking in new countries requires time, effort and perseverance [42].
- Success requires long-term effort and commitment and the ability to invest cash, time, people and management attention with the expectation that the pay off will come beyond what is considered a normal time horizon [42].
- New, business practices and business cultures are often difficult to understand either because of the complexity of cultural norms or due to the inaccessibility of ethnic or informal networks [42].

Thus, as a consequence the enterprise will need to build capabilities in each region, which will demand additional and specifically tailored strategic investments in resources, assets and competencies. Typical markets and entry modes are detailed in Figure 2.4.

2.2.2.4 Organisational Capabilities

When the enterprise reaches a point that it needs to translate strategic decisions into the proper organisational mechanisms for each region, a global network of capabilities are required [45]. According to Lasserre [42], the following questions are likely to arise:

1. What is the proper organisational structure, geographical, global or regional?
2. Should the enterprise set up regional headquarters?
3. Should each region be represented at senior management level?
4. What degree of autonomy should country managers enjoy in product, production and marketing decision making processes?
5. To what extent should planning, budgeting and performance evaluation systems be adapted or transformed to fit the regional specifics?
6. How should local managers be recruited and trained?
7. How should expatriate managers be managed?

With the introduction of enterprises to new countries a common problem of adaptation can be found [46]. This is due to cultural and business differences of the countries, in that the enterprises do not alter their business processes, systems and norms

specifically to fit their new context. Therefore, vicious circles may tend to develop: a relatively weak low profile presence, fails to lead to cumulative internal knowledge of the region and tends to perpetuate ad hoc and inappropriate business procedures. These, in turn fail to generate adequate institutional and financial support for the region at the enterprise's headquarters. This circle inevitably leads to a weak, low profile presence. To overcome this problem the enterprise will have to learn [47] and design organisational facilitators to implement its global strategy. These facilitators could include:

- The appointment of a senior manager in charge of each region
- The creation of a 'regional orientation' through regional networking and the establishment of local headquarters where deemed appropriate.
- The development of a 'regional spirit', an orientation which encourages the managers to build and act on a sense of mission in a particular country or region, such as Hong Kong or the Middle East.
- Most importantly, the capability to operate a complete transformation in the way the enterprise structures its problems and implements its decisions.

2.2.3 World Class Manufacturing

Contemporary enterprises strive to be World Class. Over the last 30 years, Japan's manufacturing success has been driven by the significance of good management practice and principles. Its industry has regularly established new standards for productivity, quality and time-to-market, which have changed the basis for global competition. The term World Class Manufacturing (WCM) was first used by Hayes and Wheelwright [48] to describe enterprises that achieve competitive advantage through the use of their manufacturing capability as a strategic tool. Developing business excellence and attaining a competitive advantage demands much more than just getting the right product and price. WCM was then popularised by Schonberger [49] who developed the concept upon a set of 16 interacting principles and provided examples of world class manufacturers. Although, the term was not defined, he postulated the goal of WCM to be 'Continual and Rapid Improvement' in the areas of:

- Customer Service

- ❑ Quality
- ❑ Cost
- ❑ Lead-time
- ❑ Flexibility

Since these initial studies, a number of authors have undertaken additional research and further developed the work. Todd [50] offers the definition, 'world class means being the best in your field in the world', whilst Gunn [51] focuses upon the role of technology. Over the last decade the Department of Trade and Industry (DTI) has supported the concept further with a series of booklets [52] [53] and 'Best Factory Award' competitions [54]. The DTI proposes:

'A world class manufacturer is one that can compete with the best anywhere in the world'

AND

'The pursuit of ideals of world class manufacturing is fundamental. It is a main aim for which other manufacturing techniques, like Just-In-Time, Manufacturing Resource Planning, Total Quality Management and so on - are contributory factors.'

Thus, WCM can be seen to be more of an objective than a methodology. Enterprises cannot expect to achieve much success by just adjusting some portions of their old business and manufacturing systems. They need to build an enterprise, which can self-change and self-improve continuously. Regularly, empirical research projects are undertaken to monitor and test relationships described as comprising WCM, such as the 'WCM Project' [55]. The DTI [53] and many others [56] [57] have also provided benchmarks that companies may expect to achieve if they have attained WCM status. Examples of these can be detailed as:

- ✓ On-time Delivery performance of 100%.
- ✓ Fully Documented Processes and Responsibilities.
- ✓ Quality owned and controlled by everybody.
- ✓ Reject Rates of less than 10 part per million.
- ✓ Stock Accuracy of 99%.
- ✓ Inventory Turns > 100.
- ✓ 100% BOM Accuracy.

- ✓ Product development < 7 Days.
- ✓ Flexibility to cope with rapid changes in product volume and mix.
- ✓ 10 Days Training Per Employee Per Annum.

The problem related to this endeavour is one of ambiguity. What is meant by 'best in the world', and 'can compete'? There are several concerns that can be raised about this typology of list. First, they use the assumption that enterprise strategies, markets and problems are really the same. ETO and MTO enterprises operate in completely different formats to ones, which deliver directly from stock. Secondly, the lists are regularly out of date as rigorous global competition drives up the performance measures. Although very informative, the most that these lists can ever hope to act as are guidelines, providing rough evidence of potential competitor performance.

2.2.4 Competitive Advantage and IT

Porter [58] [59] has provided illustrations of the ways in which IT and business systems have actually been used for competitive advantage. He has developed a number of frameworks to assist an enterprise's management in integrating the considerations of information systems and technology in formulating corporate strategy.

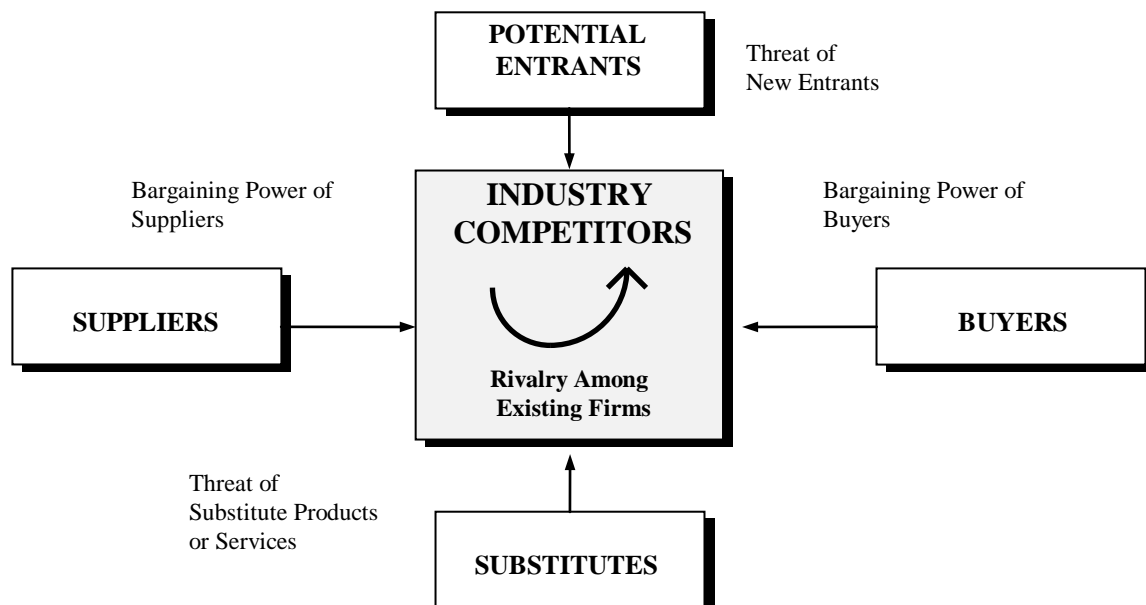


Figure 2.5: *The Five Forces, that Determine Industry Profitability [59].*

Five forces have been identified that determine an industry's profitability. They determine the degree of profitability as they influence the prices, costs and desired investment of enterprises in an individual industry. The value of each force is a function of the industry structure, or the underlying economic and technical characteristics of an industry. These forces can be seen in Figure 2.5.

Porter states [59] that enterprises generally adopt one of three generic strategies for achieving above average performance in an industry: cost leadership, differentiation and focus. The focus strategy has two variants, cost focus and differentiation focus, Figure 2.6.

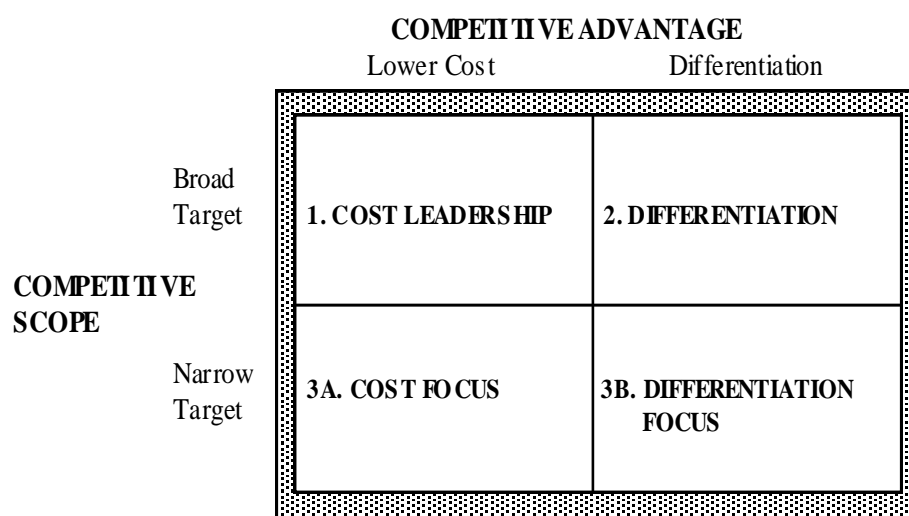


Figure 2.6: *Generic Competitive Strategies* [59].

The notion underlying the concept of generic strategies is that competitive advantage is at the heart of any strategy and achieving competitive advantage requires an enterprise to make a choice between them. An enterprise being all things to all people is a recipe for strategic mediocrity and below average performance. Each of the different strategies involves a fundamentally different path to attaining competitive advantage, combining a choice about the type of advantage desired with the limit of the strategic target is to be achieved.

1. **Cost Leadership:** This strategy requires the aggressive pursuit of cost reduction, avoidance of marginal accounts and trimming back of non direct value adding

activities. Having such a low cost position provides the business with good returns despite strong competition [60].

2. ***Differentiation:*** This means differentiating the product or services offering from the company, creating something that is unique. Differentiation provides some insulation because of brand loyalty of customers and resulting lower sensitivity to price. However, achieving differentiation often precludes against achieving high market share [60].

3. ***Focus:*** This means focusing on a particular buyer group, segment of the product line or geographic market. The strategy rests on the premise that it is able to serve a narrow market segment at lower cost than a company with a wider product range. [60].

Competitive advantage is constantly moving [61] and is a function of either providing comparable buyer value more efficiently than competitors (low cost) or performing activities at comparable cost but in unique ways that create more buyer value than competitors and, hence command a premium price [39].

IT strategy can lead to changes in an enterprise's markets, products, services and financial position. Parsons, [62] shows how the use of IT can manipulate various market forces such as buyers, suppliers and competitors. He has identified that technology strategy can have an impact upon product differentiation, cost reduction and the ability to successfully support a single product or a particular market. Galliers [63] has built upon previous work by Ives and Learmonth [64] and Cash and Konsynski [65], to provide a summary of the potential uses of IT to combat the competitive forces, as detailed in Table 2.3.

The examples of Merrill Lynch's Cash Management Account (CMA) system, McKesson's Economost and American Airline's SABRE, [66], can be used to describe the strategic effects of IT application. In recent times the list of popular strategic systems has grown, but there has been very little empirical analysis to evaluate which, if any have resulted in sustainable competitive advantage. Competitive advantage can be seen to stem from individual attributes that enable an enterprise to maintain a leading role within its chosen industry. There are two basic factors that can create this advantage [39]. These are comparative efficiency, which allows an enterprise to produce its products or services at a lower price than its competitors and bargaining power, which allows an enterprise to create favourable trading conditions with its

customers and suppliers. Comparative efficiency is determined by internal and inter divisional efficiency whereas bargaining power is determined by items such as product features, switching costs and search related costs.

Competitive Force	Potential Impact	Potential use of IT for Competitive Advantage to Combat Impact
New Entrant / Competitor	<ul style="list-style-type: none">• Greater competition• Greater customer choice• Reduced prices	<ul style="list-style-type: none">• Establish entry barriers• Raise/introduce switching costs• Differentiate product(s)• Limit access to distribution channels• Ensure competitive pricing
Buyer / Customer Power	<ul style="list-style-type: none">• Reduced prices• Requirement for improved quality /services• Greater competition	<ul style="list-style-type: none">• Raise/introduce switching costs• Differentiate product(s)• Ensure competitive pricing
Supplier Power	<ul style="list-style-type: none">• Higher prices• Reduced quality/services	<ul style="list-style-type: none">• Reduce switching costs• Encourage competition between suppliers• Aim to reduce supply costs/ ease supply
Traditional Rivals	<ul style="list-style-type: none">• Competition on<ul style="list-style-type: none">- price- product- distribution- service	<ul style="list-style-type: none">• Increase cost effectiveness/ efficiency• Control market access• Differentiate product/company• Ensure competitive pricing• Raise/introduce switching costs• Limit access to distribution channels

Table 2.3: *Potential use of IT to Combat Competitive Forces [63].*

The ability to maximise the use of IT and business systems for competitive advantage differs amongst various industries. It depends on the conditions within the chosen environment and the enterprise's ability to identify and exploit its opportunities. Competitive advantage can be viewed as being achieved when the enterprise receives a Return On Investment (ROI) that is greater than the norm and is sustained for a period sufficient enough for the enterprise to gain dominance in its individual industry [63]. In general, enterprises can achieve competitive advantage if they are the first to enter and succeed in a given field. The enterprise should be able to reduce costs, add value and create significant switching costs that produce financial benefit before the system is copied by its competitors [59]. It can only be concluded that by looking at detailed

planning and past strategic systems will enterprises be able to move from a leap of faith decision to a economically justified one. But, then again, there is always an element of luck in everything.

2.2.5 Small to Medium Sized Enterprises (SMEs)

It has widely been recognised that Small to Medium Sized Enterprises (SMEs) are a key element of any countries industrial base. Levy [20], applies the designation “SMME” to small and medium sized manufacturing enterprises which have 500 employees or less. For the purpose of this work, the acronym SME is utilised as the thesis' content is related to the manufacturing environment. Additionally, the term of SME refers to both enterprises, which are act independently or as an autonomous part of a larger organisation. This factor is considered key as SMEs are now regularly involved in M&A activity [5] and operate as part of integrated supply chains [15] [19].

SMEs are being squeezed from all directions and have had to cultivate their own unique blend of capabilities in their struggle for survival and ultimate success. Their customers are demanding higher quality products and services; the larger companies which SMEs supply, are demanding ever-higher standards in the quality of components and service. Thus smaller enterprises require a system of manufacturing management and control that can be readily adapted to suit product and process flow. 'Such a system requirement needs to be devised and documented in order that the appropriate system can be specified' [67]. Enterprises must not only compete and achieve success in the contemporary issues of quality, speed and price, or “*better, faster, cheaper*”, they must look to global and international diversification as well [68]. The question of “How do SMEs go about delighting their customers and becoming effective?”, is one that poses considerable problems for the majority of these businesses.

There are many factors that can be identified as barriers to achieving competitive advantage and growth [69]. The Cambridge University Business Centre [70] lists the following barriers to growth ranked by order of significance.

- Inadequate overall growth of market demand.
- Increasing competition.

- Lack of management skills.
- Limited availability and high cost of overdraft or expansion finance.
- Lack of marketing and sales skills.
- Lack of skilled labour.
- Difficulties in implementing new technology.
- Access to overseas markets.
- Availability of appropriate premises.

Levy [20] proposes that barriers to growth can be grouped together under three headings, technology, skills and finance. A fourth group, the modern concept of 'business processes' is suggested by Denton and Hodgson [13].

2.2.5.1 Technology

SMEs need to maintain a competitive edge for survival. It has been concluded that 'all the surveys lead to the same conclusion: smaller firms must keep pace with technological change if they want to maintain a competitive edge' [71]. The population of SMEs can be broadly categorised as technology intensive and technology contingent [13]. The technology intensive SMEs can be seen as specialist high technology companies which use more advanced technologies and systems for the disciplines they are involved in. They are often on science parks and have, in many cases, spun out of larger enterprises. The picture regarding the technology contingent SMEs is somewhat different. They use low technology and are forced to adopt the new combinations, (technology and systems), because of market pressures. These may be seen in smaller industrial estates and are often privately owned.

All these enterprises find it very difficult to keep abreast of new developments in each of their individual areas, and really use technology to improve business performance [72]. Attendance at trade exhibitions and new product launches together with subscriptions to relevant journals all require additional time and expenditure. Even if new equipment is purchased, a degree of uncertainty and risk may be incurred because inadequate analysis, specifications, planning and training have been undertaken. It is proposed by Pollard and Hayne [73] that there are many differences between the adoption of IT in large and small enterprises:

- ◆ Few stakeholders involved in SMEs mean there are likely to be fewer problems in terms of organisational politics [73].
- ◆ SMEs have diminished resources available to implement IT solutions [73].
- ◆ SMEs are able to complete the transition process much faster and possess greater flexibility to realise the full benefits of any new IT [73].
- ◆ IT allows SMEs to increase their market scope and secure their position through increased communication with higher tier, larger enterprises [73].
- ◆ It is easier for SMEs to spawn new business and implement new organisational forms.
- ◆ Technology can lead to greater control of internal operations [73].

2.2.5.2 Skill

In skills such as accounting, management practice and marketing, SMEs are under considerable strain. International comparisons [29], repeatedly show that, apart from the top technical level, the UK workforce is seriously under-qualified. This is a major problem for SMEs because a large proportion of the fresh, well-educated graduates are recruited by large enterprises in pre-graduation recruitment fairs, and graduates with lesser qualifications are tempted into service-based enterprises which offer higher salaries and better conditions than SMEs can provide. Also, in recent times there have been shortages of generalist engineering skills, which are the backbone of many SMEs. Without an appropriate combination of skills, the prospects for success are lowered further. Further evidence [74], suggests additional reasons: strategic planning is not conducted professionally; there is inadequate use of financial and management information; there is a reluctance to employ proven management techniques or seek advice from professional advisors.

2.2.5.3 Finance

This is generally expressed as the most limiting factor associated with the development of SMEs. In the UK, independent SMEs are reliant upon high street banks for the major proportion of their external borrowing [75]. However, despite the dramatic increase in numbers of SMEs over the last decade and the subsequent rise in bank lending to this sector, the relationship in the UK has been far from ideal in comparison with other countries. This is due in part to competitive pressures facing UK banks and the value of the property collateral that underpins so much borrowing. The SMEs'

relationship with its bank is of crucial importance. This is particularly the case when the enterprise is experiencing difficulties or wishes to undertake capital investment programmes or acquisitions. As the majority of independent SMEs are privately or jointly owned, raising alternative cheap finance is difficult because the entrepreneurs are notoriously reluctant to permit outside interference in their business and to cede any control over the equity capital. In the cases where this has happened, it has often ended in the replacement of the original owner who then leaves the business [76].

In addition, to the barrier of direct finance is the underlying issue of cash flow. Cash starvation is a common reason for SMEs getting into financial difficulties when trying to attain growth, adopt new systems and achieve comparative success. Incorrect assumptions and forecasts made about future orders and investments can stifle the growth of the enterprise. This can lead to a snowball effect in operational problems, when money is in short supply the enterprise can become unable to finance its component suppliers and ultimately cannot purchase the components needed to produce its products. Depending on the nature of the sales contracts, the enterprise may not receive payment until its manufactured products have been delivered. In this case, the enterprise would enter a cycle of excessive lead-times, high inventory and work in progress, low throughput and shrinking cash flow. This vicious cycle can be potentially very difficult to break free from [77].

2.2.5.4 Business Processes

The concept of business processes is one that has come to the fore in recent years. A business process can be seen as a set of logically related tasks performed to achieve a defined business outcome. For example, order fulfilment is a process, comprising a series of tasks: receiving the order, entering it into a computer, checking the customer's credit, allocating and provisioning the products, picking the items out of the stores and despatching them, and so on [78]. Each individual enterprise can be viewed as being built up of core processes, which flow through it. Typically, it is suggested by Foddy [79] there may exist around six of these core processes within an enterprise and they can be grouped together to form a set of horizontal, customer-oriented processes rather than vertical organisational functions.

The way in which an enterprise operates internally can be directly compared to its degree of achievement. The successful design of processes is of fundamental importance to SMEs [13]. Unlike in the larger manufacturing enterprises, how each individual acts and undertakes his/her work can have a noticeable influence on the operation of the entire enterprise. In SMEs there may exist less opportunity for process-based thought or cross-functional reorganisation. This can be related to the fact that many SMEs have evolved into and operate around enclosed departments holding relatively small numbers of people. In terms of this practice, SMEs can sometimes become environments where “knowledge is power”, so separate functions, such as sales and manufacturing may work independently of each other and try to maintain their independence. If growth opportunities are presented individual functions may contest for larger proportions of the additional work and staff, without necessary reference to the business needs of the enterprise [80].

For many SMEs the problem of inefficient processes has been building up over a period of time. The path to the problem may be related, in part, to the beginning of the business. One day, the owner of the enterprise recognised that he/she did not have enough time to handle a certain task, so it was delegated to a subordinate. The subordinate improvised. Time then passed, the enterprise grew and the new manager brought in his own team to help him cope. They all improvised. Each day new challenges and special cases occurred, and the staff all adjusted their work accordingly. The tangled web of special cases and quick fixes was then passed on from generation to generation. 'The ad-hoc then became institutionalised and the temporary enshrined', [81]. When somebody finally comes along and questions the madness, “*because we have always done it*”, comes the reply. To steer clear of this scenario must be a principal aim for an SME or any other organisation.

2.2.6 Technology Transfer

The transfer of technology is becoming a worthwhile issue in economically oriented research. It is also an important variable of the majority of global economic policies. In today's modern world there can be seen to be striking inequalities between the rich and the poor nations. People all over the world are looking for opportunities to develop

their low standard of living and to lessen the existing gaps between and within the developing and developed world.

The most appropriate method of achieving this end can be to use the application of modern technology. The process of technology transfer has a great impact on the receiving nation's social and economic development. Technological modernisation is an important precondition for the creation of an independent national economy which can supply the people with homes, food, education, health care and fields of other cultural activities [82].

When an enterprise desires to become a global concern the impact of the systems it aims to employ should be thoroughly studied. This can involve planning, organisation and co-operating in many diverse areas. It may not be just enough to acquire production capabilities; rather it is the basis of such capabilities that must be acquired. Using a detailed systems approach, both the investing enterprises and the nation can tailor the technology to succeed and benefit all [83]. There are several issues of equal importance for successful technology transfer, these are:

1. Science and technology transfer [83].
2. Forms of technology transfer [83].
3. Criteria for selection and evaluation of, appropriate technology [83].
4. Management of technology transfer [83].
5. Systems underlying technology transfer [83].

The appropriateness of technology can only be assessed in relation to the nation's markets, infrastructure, workforce and government policies. The question of "What do the developing countries really need on their transformation to industrialisation?" should be considered as an aid to developing strategy. Some countries may have developed the capacity to evaluate and select imported technologies suitable to their own requirements while others may need to acquire the necessary experience of adapting to foreign designs and production processes.

The transfer of new IT and business systems to developing countries can have the adverse effect of increasing the obsolescence of their existing industries, services

and development strategies. In relation to IT transfer, three general conclusions seem to be valid.

1. That an, erosion of their advantages in low labour cost and mature industries is taking place due to changes in products and manufacturing processes. The final outcome of this trend will depend largely on the lesser, developed country's response at the macro and micro level [84].
2. That the use of IT in developing countries is limited and the gap between IT use in rich as opposed to poor countries is increasing. With the exception of a few countries, most less well developed countries have not developed policies to confront the challenge at the different levels (e.g.: skills) [84].
3. A new reality and opportunity is emerging with the globalisation of services. Redressing trends here seem to be a priority, essentially because the situation is still in a state of flux. The lower barrier to entry in services offers to some developing countries opportunities that were impossible to imagine with tangible products, among them the possibility of reaching consumers directly [84].

Over the last thirty years, the UK government has endeavoured to aid SMEs with technology transfer using programmes such as the Teaching Company Scheme (TCS). This scheme aims to enhance the competitiveness of SMEs by building technology transfer partnerships between Universities and local Industry. TCS is sponsored, by the DTI and related research councils, such as the EPSRC [85]. From a business review [86], it is concluded that the economic impact of the scheme is 'substantial' and it calculates that to date, in terms of net cumulative additional activity, each £1 million of TCS support generates:

- 62 Jobs.
- 161 Company Staff Trained.
- An additional one-off £0.86m rise in profit, spread across the participant enterprises, for the duration of their programmes.
- An additional annual £3.1m rise in profit, spread across the participant enterprises, after programme completion.
- The facilitation of £3.5m investment in plan and machinery.

The TCS has demonstrated the importance of collaborative technology transfer in the modern day business environment. It has been a highly successful and versatile mechanism for diffusing best practice and innovation to SMEs. Additionally, universities benefit from improved industrial links and associates registering for further academic courses. The key to such methodologies is that the concept is more than just the technology involved. It is about partnerships, people and progress. The common goal, suggested by Fleissner [87], provides us with a valuable target to aim for, 'Technology has no end in itself, but should serve the people'.

2.2.7 Critique - Business Arena

It can be recognised that there exists a plethora of work regarding, the current status of manufacturing, the impact that market globalisation is having upon manufacturing enterprises as they strive to achieve success, and the high-level importance of IT as a competitive advantage enabling tool. What becomes evident from this literature survey sub-section though, it that there is a research gap in how SMEs may focus upon specific strategies and techniques to meet Porter's [59] five forces of industry structure and achieve profitable growth and globalisation, with or without the deployment of IT. There is no apparent consensus as to combinations of strategy or direct routes that may be applied to a particular global business situation or problem.

It has been identified that SMEs have many barriers to growth and do not necessarily have access to low cost professional IT services or systems. What remains problematic is how industry and academic bodies should practically support SME decision and implementation processes, regarding business strategy and IT systems. The provision of professional, low cost and effective IT-based methodologies appears to be at the forefront of SME requirements to progress their business successfully.

2.3 Management Concepts

Over recent years, management theory has appeared to be facing an identity crisis of considerable proportion. A number of new wave methodologies and approaches, together with re-invented old ones, have been introduced as the definitive way to fantastically improve any enterprise, e.g. BPR, Lean Production, Agile, Virtual and Holonic Manufacturing, Just-In-Time (JIT) and Total Quality Management (TQM), etc

[88] [89] [90]. Some enterprises have been forced to utilise these major transformation processes by external pressures, other have initiated the change processes themselves. The literature is scattered with spectacular success stories as well as surveys, which indicate worrying failure rates. The aim of this section is to understand the key management concepts that are applicable to this thesis.

2.3.1 Strategic Management

Strategic management is required to combat the complexity and the sophistication of business decision making. In previous times every respectable enterprise held a business strategy. It typically advocated the incremental expansion of existing products, the maintenance of the norm and the extensive purchasing of any new technology. More recently all of these hopes have been thrown to the wall due to forthcoming recession, cut backs and rationalisation which have been enforced. The changing economic climate has lead to the fact that there was no point in strategy or investment as it was impossible to estimate what would happen next. Foyer [91] comments, 'Without strategy it is hardly possible to take advantage of opportunities because nothing is ready when the time comes'.

Strategic management is defined by Pearce and Robinson [92] as '*the set of decisions and actions resulting in formulation and implementation of strategies designed to achieve the objectives of an enterprise*'. Key aspects of a formulated strategy usually encompass focusing the manufacturing activity on the customers and their needs, developing more effective business processes and investment in both people and physical assets [93]. Traditionally, the hierarchy that is responsible for formulating business plans typically contains three levels.

These are from the highest, the corporate level, the business level and the functional level. The corporate level is composed of the board of directors and the chief executive and administrative officers. They are responsible for the performance of the enterprise as a whole, and for achieving the non-financial goals of the enterprise. The business level is composed of the managers who follow the directions decided upon by the corporate level and subsequently transfer longer-term strategy into divisional and strategic objectives. Finally, the functional level generally consists of elements regarding research and design, finances, marketing and human relation

strategies. Each function manager is responsible for developing the annual objectives and short-term strategies required of his own discipline.

Typically, as manufacturing enterprises are move towards business process focus, a change from more hierarchical management organisation to flatter management structures may be required. A method to undertake this transition could be to remain with the same strategic model, but to identify informal top management teams that encompass all aspects of a product's life cycle. These functional teams could direct the enterprise by consensus management and empowerment [93] [94], but problems such as accountability and a lack of overall direction may occur.

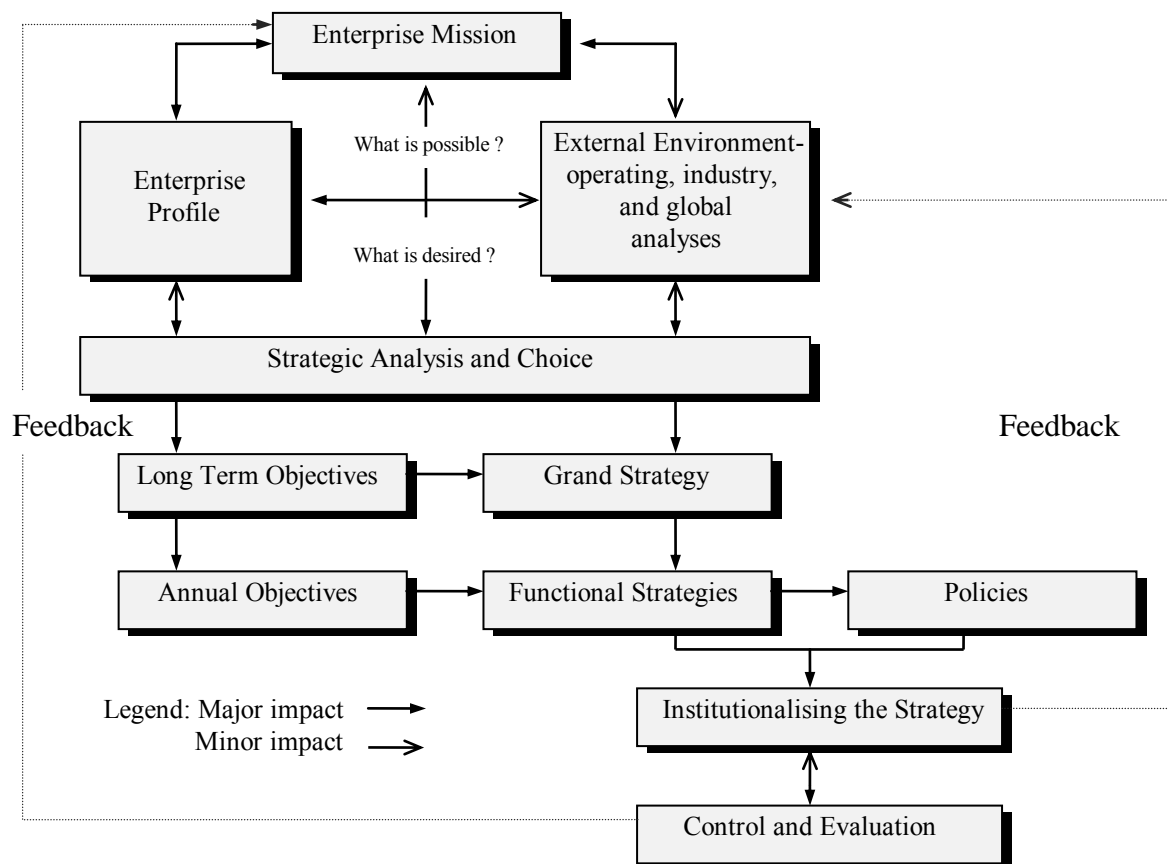


Figure 2.7: *Strategic Management Model [91]*

The principal appeal of applying strategic management methods is the expectation of it leading to increased profit for the enterprise. Research has shown [95] [96], that in general, enterprises that are long range planners consistently outperform non-formal planners in terms of widely accepted financial measures. This, though, can be still opened up to question. The benefits of strategic management exercises may also show

themselves in a number of other ways than financial figures. Behavioural and experience gains may be discovered which can be added to the equation to help justify the approach; irrespective of the chance of improved financial performance, Figure 2.7.

2.3.2 Global Management

Global management requires a broad base of relevant skills as well as a wealth of experience and practice that are subsequently reduced into a coherent body of usable knowledge [32]. Much interest is concentrated on global management. Whole nations are based on global commerce and others are frequently undermined by it. The knowledge required by ancient traders has changed considerably since the evolution of the modern global market place, but the fundamentals remain constant [40].

Global management is concerned with buying, selling, moving goods and funds, together with supplying services across borders [41]. This trade of goods has led to the wealth and enrichment of the manufacturer, and in some cases the exploitation and misery of their counterparts. The knowledge developed in global management can be divided into three distinct approaches, observation, experience and theory, Table 2.4.

APPROACH	DESCRIPTION	METHOD	EXAMPLE
OBSERVATION	Observing facts and phenomena which stimulate questions and provide data for answers	Systematic assembly of data (including statistical tables) and checking on hunches	Company finds exports to country X declining while market increasing
EXPERIENCE	A bundle of activities which together constitute the functions of the international manager	Recording, comparing and interpreting, experience (including case studies)	Decision process on whether to withdraw or to manufacture locally (and if so whether by licensing or direct investment)
THEORY	Considerations which together build a body of knowledge and elements of theory	Employing relevant concepts, methods and theories to understand the phenomena and activities and to predict change	Examine theories of comparative advantage, imperfect markets and corporate expansion

Table 2.4: *Global Management: Approaches to the Subject, [44].*

The Observation stems from the external environment and is detached. It collates all the relevant information, such as facts, opinions and research, and presents them into a usable form. The Experience approach originates inside the enterprise and takes us into the decision-making process combined with the examination of strategy backed by case

studies. The Theory discipline should be viewed as a unifying element that brings together all the fragmented ideas and hypotheses, developed and tested through the methodologies that are generally used in management circles. The global enterprise can be viewed as any business that undertakes trade across national borders from a general export order to the large-scale investment of capital overseas.

Global management is constructed of a large number of disciplines. These all contribute to aid in the understanding of a global enterprise. The external environment encompasses the management and the supporting disciplines and theories, such as economics, geography and enterprise design surround these together. The requirement to formulate and implement global strategies can be seen as a natural part in the improving the business development of an enterprise. Brooke [44] list common motives for global trading can take the form of:

- A search for business in different countries to overcome the effects of trade cycles [44].
- The need to reduce the impact of buying trends [44].
- The requirement to develop new products with higher margins to sustain a business [44].
- An opportunity to gain access to overseas customers [44].
- An enterprise with idle capital in a falling industry sector searching to apply its funds in a new environment [44].

There are many surface desires for attempting diversification, but the reason that is underlying them all is the requirement that the business must change to stave off its present position. Enterprise business is conducted in the future, not in the past. Today, too many enterprises follow the call of their past experiences and do not look for new opportunities and policies. The old simplicities of global trade are no longer and the distinction between the industrialised world and the others is becoming blurred [31]. The older countries are desperately trying to protect their traditional manufacturing bases while the new developing countries are seeking industrial expansion. How one best exploits these changes? is still another unanswered question.

2.3.3 Change Management

Enterprises, which ignore the concept of change, do so at their own peril. The French say that the more things change, the more they remain the same. Schlesinger et al [97]

suggest, another possibility: 'Things that do not change may not remain at all. Thus lack of change may endanger the survival of enterprise life itself'.

McCalman and Paton [98] propose that internal and external issues, which enterprises have to deal with drive the necessity for change. It is further commented [97] 'Organisational change is the process of adjusting the organisation to combat changes in the environment'.

In recent times change management has become one of the most significant management competencies, [99] [100]. The importance enterprise wide change was emphasised by the inability of one-time industry leaders to keep pace with the accelerating industry need [101]. Change in industry need that confronted many large enterprises such as General Motors, Ford and IBM were not more or less extrapolations of the past [102]. The watch word for managers of these enterprises was 'Steady as she goes'. Eventually all these enterprises saw their success eroded or destroyed by rising tides of technological, demo-graphical and regulatory change and order of magnitude improvement in productivity and quality gains made by non traditional competitors [103].

When lack of competitiveness problems arise a natural action has been for senior managers to pick up the knife and jettison the layers of under performing corporate excess [103]. Simultaneously managers are now having to study their competitors methods and develop new techniques that will allow them to survive in a changing and increasingly competitive climate. A continuum of changing factors in such an environment increases responsibilities of managers [94]. While historically many managers had to deal with internal issues, this has now changed. Today managers have what has been described as 'The Manager's Two-Front Job' [94]: on one front dealing with internal forces and constraints and on the other, maintaining a watch on the external environment for new opportunities or threats that will impact on the enterprise.

Thus requirements for change can stem from external sources. Dilemmas will exist because it is difficult to achieve two goals simultaneously. Therefore a balance is required between being able to respond to external threats and opportunities whilst being able to create order from chaos. One goal has to be pursued at the expense of another. If more than two objectives need to be reached, the task is even more

complex and difficult to achieve. Peter Drucker [104] has suggested that enterprises typically need to seek optimisation with respect to the following general functions:

- | | |
|------------------------|--------------------------|
| 1) Marketing | 5) Physical Resources |
| 2) Innovation | 6) Productivity |
| 3) Human Organisation | 7) Social Responsibility |
| 4) Financial Resources | 8) Profit Requirements |

To meet all associated objectives and react to the gains made by competitors the enterprise must change. Any change process is more likely to be effective when the costs of making the change are outweighed by resultant benefits and associated factors that motivate the change. The relationship can be explained as such, [97].

$$Change = D * M * P > C$$

Where D = the levels of dissatisfaction with the status quo,

M = the new model for managing implicit in the change,

P = the planned implementation process for making the change,

and, C = the cost of the change to the relevant stakeholders, individuals and groups in the enterprise.

Thus, in this case, change can only occur when sufficient dissatisfaction with the status quo is present in key individuals or in significant groups such as the enterprise's board. Those concerned need to articulate the new way of managing, such as identifying and placing emphasis on core processes needed to action a change. Finally the enterprise has to have a process for managing the change, e.g. BPR, that is sufficiently well planned, anticipates the resistance to the change, understands where the resistance will come from and outlines effective intervention methods. The combined cost of these factors must be greater than the cost of the change economically and emotionally to the enterprise.

2.3.4 Mergers and Acquisitions

Mergers and acquisitions are a prevalent part of the manufacturing competitive landscape. A merger is where two independent businesses join together to form one

new entity, whereas an acquisition is where an individual business takes over another one by purchase [44]. According to Compass [106], at least 30% of the leading 2000 global enterprises are currently considering an acquisition. Another 40% are potential acquisition targets themselves. Clearly, this group of enterprises consider M&As a viable growth mechanism and a valuable aspect of modern business. It is further anticipated [5] that this growth will be driven over the next few years by several factors. These can be viewed as the expansion of the global market place, greater deregulation, the rise of electronic commerce and increased competition. 'Mergers, and acquisitions can now be seen as a fact of life' [107]. The annual value of these types of transactions in 1999 was estimated to be more than \$2 trillion [108].

Although, it is difficult to forecast, the slowing of the global economy may lead to an increase in activity, as enterprises look to drive efficiencies with restricted capital. At the same time, enterprises are increasingly focussing on core competencies and moving away from vertical integration. Zrimsek [109] suggests inhibitors that may dampen this growth include:

- Lack of differentiation and a high rate of generalist focus.
- Poor return on investment measurements.
- Lack of required skills and ineffective alliances.

A successful strategic merger or acquisition can allow a manufacturing enterprise to grow revenue at a high rate by addressing many of the inhibitors and taking advantage of the many drivers. Some of the strategic reasons for entering into a merger or acquisition include the following [112]:

- Market consolidation.
- Instant presence in a new market niche.
- Streamlined and focussed services and processes.
- Augmented capabilities and acquisition of experienced talent.
- Increased capability to provide all end-to-end repeatable solutions.
- Increased critical mass for entering into a new market (Global, product line, industry and so forth).
- Increased diversity of customer base.

Entering into a merger or an acquisition can also be fraught with risks that include under-performance by the acquired enterprise, over-payment and insufficient finances to support the combined enterprise. Berry comments [110] that 'It has long been known and widely accepted that more than 50% of acquisitions fail to meet their original objectives'. This failure can, in most cases be traced to a single source: Inadequate pre-acquisition due diligence or more simply a failure to do the homework. The process of undertaking this type of enterprise change is shown below, Figure 2.8.

Acquisitions typically begin with the recognition that there is a 'strategic fit' between two or more businesses. The case is usually made on paper and is carried out at the highest levels of the enterprise, including financial justification. The due diligence phase, in which the acquiring enterprise values the assets and business of the target entity, is generally the field of accountants, bankers, auditors or outside consultants. IT is rarely considered strategic enough, to influence the perceived 'added value' that validates or negates an M&A deal. This absence of IT from these negotiations may lead to unrealistic expectations for IT cost savings, speed and ease of integration, and the maintenance of uninterrupted service [5].

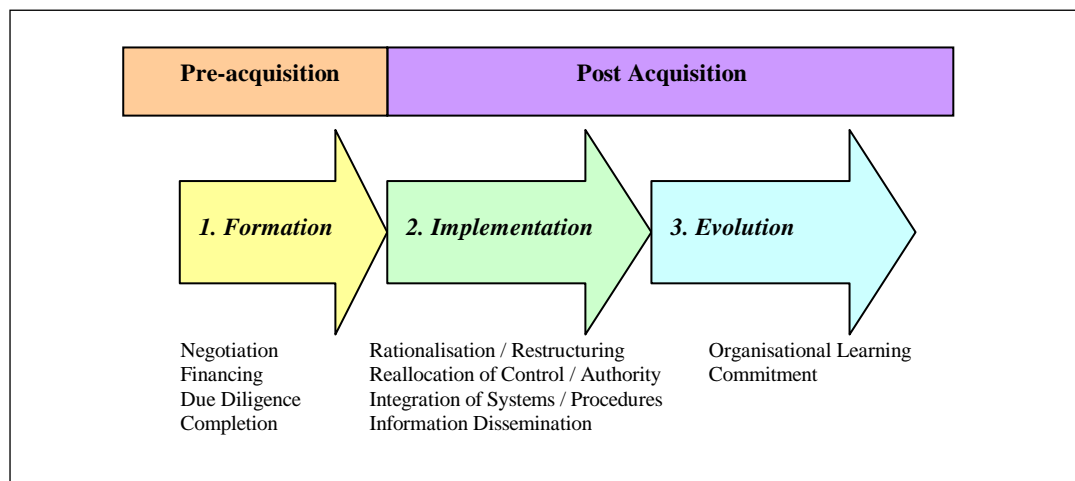


Figure 2.8: *Merger and Acquisitions Processes* [110].

An associated form of M&A activity is that of divestitures, where an enterprise splits or sells off part of its business. Divestitures pose similar technical problems to typical M&A activities, but from an opposite perspective to acquisitions. The divestiture of a business can assist the parent enterprise with achieving focus upon its key markets,

providing increased access to capital, can facilitate increased shareholder value and has the potential to remove loss making elements from the enterprises business portfolio.

As a further alternative to M&A activity, enterprise management who wish to expand their enterprise's product, geographic or customer reach may consider alliances to be the strategic vehicle of choice. In the past recent years, the number of domestic and cross border alliances has grown by more than 25% annually [109]. But this term alliance can be deceptive; in many cases, an alliance really means the transfer of ownership. Bleeke and Ernst [111] state, the median life span for alliances is about seven years and nearly 80% of joint ventures, one of the most common alliance structures, ultimately end in a sale by one of the partners within five years, This factor should be considered further by the enterprises. They further propose that there are six different types of strategic alliance [111].

- Collisions Between Competitors.
- Alliances of the Weak.
- Disguised Sales.
- Bootstrap Alliances.
- Evolution to a Sale.
- Alliances of Complementary Equals.

The implication of this knowledge for the enterprise is that if it does not anticipate the endgame, what could begin as a partnership could lead to an unplanned divestiture. The key to understanding whether an alliance is likely to lead to a sale is to project how bargaining power will evolve over time. If technology is a source of competitive advantage, an enterprise must treat licensing as a risky step that should be only taken under special conditions. Licensing fees are rarely sufficient enough to offset a loss of competitive advantage. However, Porter [59] comments that awarding licenses may be strategically desirable under a number of circumstances:

- Inability to exploit the technology
- Tapping unavailable markets
- Rapidly standardising the technology
- Poor industry structure

- Creating good competitors
- Quid Pro Quo (exchange of licenses)

The enterprise could hurt rather than help its competitive position by awarding licenses. The two most common pitfalls in licensing are to create competitors unnecessarily in the process and to give away the enterprise's competitive advantage for a small royalty fee. Licensing could be an easy way of increasing short-term profits, but it could result in long-term erosion in profits if the enterprise's competitive advantage dissipates.

Porter further comments 'that companies often fail to perceive who their potential competitors are and thus award licenses that come back to haunt them' [59]. They may license foreign companies that later enter their home markets. Similarly, many enterprises, that have licensed businesses in other industries only to have the licensees to enter their own industry.

Another concept to understand with considering this type of global enterprise activity, particularly in Japan, is Keiretsu and Keiretsu Business Groups. A Kieretsu is a sophisticated, multi-faceted management device and not a form of organisation. Kieretsu Business Groups are not trusts, cartels or conglomerates, but groups of enterprises with an intricate web of inter-enterprise relations. These groups may have profound implications for global enterprises trying to undertake transactions with major Japanese businesses. Problems occur with business understanding together with, organisation and authority transparency [112].

2.3.5 Process-Orientated Thinking

The concept of Business Process Re-engineering was first invented by Michael Hammer in 1990 and rapidly gained prominence through an article in the Harvard Business Review [81] where he stated, 'Re-engineering is the fundamental analysis and radical redesign of business processes to achieve dramatic improvements in critical measures of performance'.

Since Hammer's seminal article caught the attention of the business community, an enormous amount of interest in BPR and its implementation has been evident. The term BPR, once heralded as a 'corporate panacea that could cure all ills' [113], has now become accepted as a catch-all to include other process initiatives such as; Business

Process Innovation [2] [114], Business Process Re-design [23] [115] [116], and Business Process Management [117] [118] [119], all combined with 'good business sense'.

According to Business Intelligence, BPR research specialists, 'Reengineering is about making radical improvements in performance through the reorganisation of the core processes', [120]. Hammer and Champy [1] argue that business re-engineering is the next business revolution and is not about fixing anything but about starting all over from the basics, ...beginning from a clean sheet of paper'. BPR can be seen as a reactionary process born from recognising that continually restructuring the enterprise leads ultimately to a dead end. Many enterprises for some time have been practising the three 'Rs': redirection, reorganisation and restructuring, but now they are being motivated to apply a fourth, re-engineering, to their ever expanding lists of new strategies [121].

The BPR approach advocates the view that an enterprise is composed of processes which operate as the business undertakes its work. In the same way that raw materials and components flow through a manufacturing plant as they are turned into final products, the business is seen as a group of end-to-end processes through which information and knowledge flow. Davenport and Short [23] define a process as 'a set of logically related tasks performed to achieve a defined business outcome'. This definition is akin to Pall's definition [122], 'The logical organisation of people, materials, energy, equipment and procedures into work activities designed to produce a specific end result'. It can be accepted that these definitions mean a process starts and finishes with internal or external customers, who are served by the process. Davenport and Short, further propose that processes have two important characteristics and imply a strong emphasis on how work is done within the organisation [123]:

- They have customers; that is, processes have defined business outcomes, and there are recipients of the outcomes. Customers may be either internal or external to the firm.
- They cross, organisational boundaries; that is, they normally occur across or between organisational sub-units. Processes are generally independent of formal organisational structure.

This process thinking has become even more widespread in recent years, due largely to the development of TQM principles, such as that of Crosby [124]. Enterprises who wish to improve the quality of operations have been compelled to consider the entire process, as opposed to just a particular task or business function. This process-based perspective seems to encourage a holistic view of the activities, which are required to satisfy a customer's need. By conceding that the activities along the process are largely dependant upon each other, it is clear that to improve one part of the process in isolation will not have a major effect upon the process flow. Consideration to the whole process must be paid.

Traditional techniques of managing IT enabled change such as Manufacturing Resource Planning (MRPII), and more recently ERP, implementation methodologies are still valid, but may not necessarily conform to the changing business requirements of contemporary enterprises. BPR can provide opportunity to remould proven ideas into a new framework, which can be used to alter the functionally based way in which we generally think about enterprises. The need to change can be related to, 'aiming to overcome some of the problems raised by Tayloristic view of structural specialisation' [126], particularly where managers are hindered from enterprise-wide improvement because they are only responsible for functions and departments, not processes. However, a process focus may not necessarily suit all types of business and enterprise or the activities undertaken within [125]. By implementing BPR, enterprises may still make use of Kaizen activities [127] and other change programmes but can reorganise them into a broader, better understood context.

BPR has been one of the most influential change 'bandwagons' of recent years due to the massive benefits it may deliver and its potential to provide extensive competitive advantage [128]. Whilst enterprises such as Ford, Hallmark and Kodak [78] [129] have all claimed large scale success, others such as Teleco [130] have not fared so well, and the methodology has been increasingly seen as a euphemism for redundancies and factory closures. Amongst all of the marketing hype about BPR, there is little initial, empirical evidence to support its effectiveness. More recently, additional research work has been undertaken [131] [132] [133] [134] in this area to consolidate a developing base of application knowledge. Little work through has been undertaken with respect to the application of BPR in SMEs. Roberts [135], proposes a

methodology to document the needs of an adaptable management control system as part of a BPR process, but survey work [136] suggests that around 95% of SMEs have not even heard of BPR. The Innovative Manufacturing Initiative [132] cite acquisitions and collaboration, together with cost reduction as the main two drivers for enterprises undertaking a BPR programme.

Some enterprises may already be using component parts of BPR, but linking them together needs a clear understanding of the principles involved, a strategy and the need to be 'very' agile and open to deal with new, unique, circumstances. Davidson [140] comments, 'Field research at leading enterprises suggest that business transformations occur in three independent phases, each offering its own challenges and benefits'. These three phases are summarised as follows; Phase 1 stresses the pursuit of operating excellence, beginning with automation and re-engineering activities. Phase 2 builds upon the capabilities and infrastructure created in Phase 1 to develop, improve and focus the range of products and services offered to customers. In Phase 3, new enterprise business units can appear, as new product and service offerings become independent ventures. Also, capabilities developed in the initial phases of change may become core competencies that redefine the original enterprise. This three phased approach is detailed in Figure 2.9.

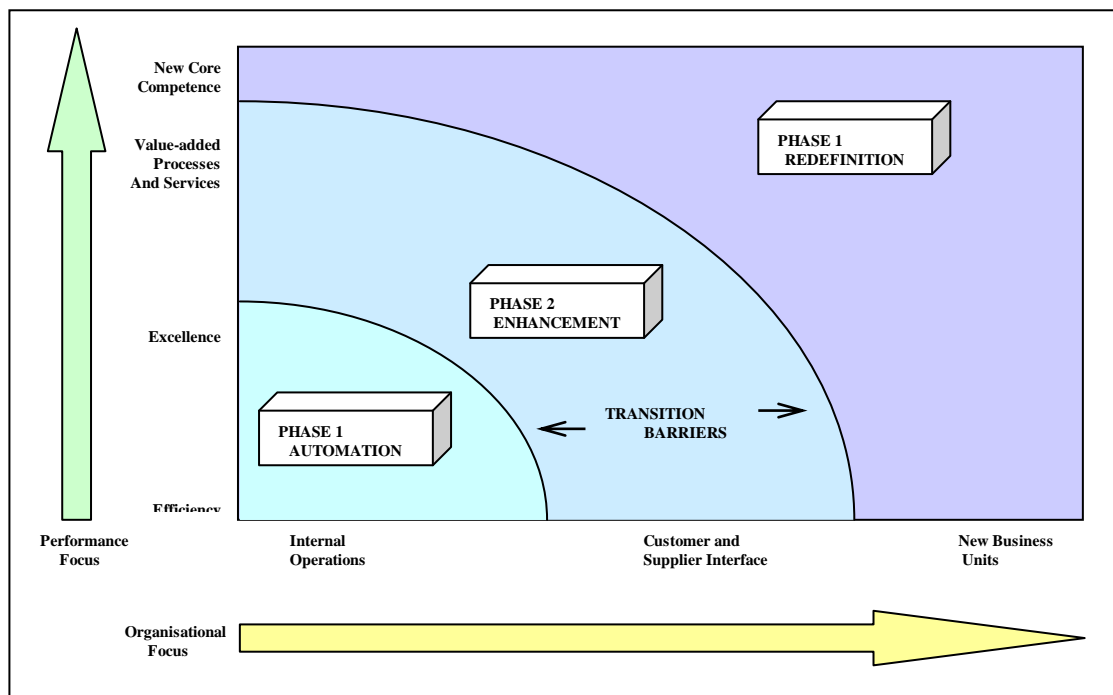


Figure 2.9: *The Three Phases of Business Transformation* [137].

Once the main business processes have been identified the enterprise can be automated. The Xerox group based their redesign on a strategy taken from the Boston Consulting Group [121]. The first was the organisation that makes up the formal procedures and enables the enterprise to function. The second was the people with a focus on the new skills required, to operate within the new environment and the third, was the informal networks and practices that link people together, such as values and culture.

2.3.6 Enterprises and Engineering

Manufacturing Enterprises are unique, complex, chaotic and organic systems, which have to be managed for their internal affairs, but more importantly for the many relations to the different environments in which they undertake business [19] [138]. Rozenfeld et al, propose [139] 'The main goal for manufacturing enterprises is to become or stay competitive'. Therefore, manufacturing enterprises must highly optimise their processes, productivity and product quality, in order to delight their customers and achieve this goal. One major approach that may be distinguished by its fundamental philosophy, techniques and tools is the new discipline of 'Enterprise Engineering' [3] [138] [140] [141] [142].

Vernadat [3] proposes that the rationale behind this concept is that enterprise systems can be engineered in a systematic way like any other complex system. However, we now have to involve people and resources that can be highly non-deterministic in nature [143]. Bernus and Nemes [144] comment that, 'manufacturing enterprises are really socio-technical / socio-economic systems rather than technical systems alone'. Additionally, Billing and Mauderer [145] state, 'Present manufacturing system planning and development often show significant deficits regarding the collaboration between developers with different backgrounds'.

Enterprise Engineering is therefore at the junction of many methodologies concerned with the design, continuous improvement and re-engineering of a manufacturing enterprise [3]. It has a foundation comprised of the engineering concepts of manufacturing, systems, information, process and software, but adds the extra dimensions of global management, human resources, economics and ergonomics. All of these can be seen as important aspects to consider for structured, systematic design and implementation of manufacturing enterprise systems. In particular, people are crucial as they 'are no longer seen as imperfect machines, but rather as an extremely

valuable and highly flexible resource' [146]. Typical approaches to creating and developing a manufacturing enterprise are built upon the foundation of 'bringing people together and providing them with a structure and technology for doing work' [147]. Weston [19] [148] builds upon the use of ISO 14258:1998 which proposes that three classes of activity are required, during the plan/build, use/operate and recycle/dispose life-phases of an enterprise, specifically:

- 1) **What** an enterprise should do? (*Activity class W*).
- 2) **How** it should structure itself and use technology to achieve its goals and objectives? (*Activity class H*).
- 3) **Doing** product and realising activities in a structured and technically supported way (*Activity class D*).

These, *What*, *How*, and *Do* classes can be separated into three meta life-phases (Table 2.5) to depict typical enterprise activities. Of course, these phases are not purely sequential or global. Parts of the enterprise may exist already and are being utilised, while others are being re-engineered or implemented. There may also be iterative loops within and between them. Notwithstanding the simplicity of this table, enterprises in reality have to undertake very complex groups of processes and activities when delivering customer products and services [23].

	"What" Activities	"How" Activities	"Do Activities
Plan and Build Phase (e.g. before sell / buy title transfer)	<ul style="list-style-type: none">• Develop Goals• Define Strategy• Define Product Needs	<ul style="list-style-type: none">• Develop Requirements• Define Concept• Design Product• Plan to Produce Product• Plan to Support Product	<ul style="list-style-type: none">• Procure Parts• Produce Product• Test Product• Ship Product
Use and Operate Phase (e.g. after sell / buy title transfer)	<ul style="list-style-type: none">• Define Support Needs• Define Use	<ul style="list-style-type: none">• Define Use Requirements• Define Support Requirements	<ul style="list-style-type: none">• Use the Product• Support Product
Dispose and Recycle Phase (e.g. after product is no longer useful)	<ul style="list-style-type: none">• Define Recycle / Dispose Needs	<ul style="list-style-type: none">• Define Recycle / Dispose Requirements	<ul style="list-style-type: none">• Recycle Product• Dispose Product

Table 2.5: *Example What, How and Do Enterprise Activities, [ISO 14258].*

Throughout the lifecycle of an enterprise it is principally people who decide the purpose of an enterprise and *how* it should function, [149]. People then *do* a significant proportion of the activities required to make it operate. Enterprises keep changing, as nothing is permanent in the organisational structure, manufacturing practice or IT infrastructure of an enterprise [144]. People are constantly challenged to make decisions and implement modifications. This can be attributed to unknown cause and effect influences, which occur irregularly as a result of political, economic, social and technical (PEST) change [150].

Figure 2.10 shows a very simple representation of a typical manufacturing enterprise. It depicts the decomposition of the internal enterprise into functional units. These may be duplicated throughout the enterprise and be scattered across the globe. Therefore, manufacturing enterprises may be loosely characterised as a combination of individual business units, which operate in a globally integrated manner to add value to materials, components and assemblies (supplied by customers) in such a manner that the enterprise can supply products and services to customers at a profit [19].

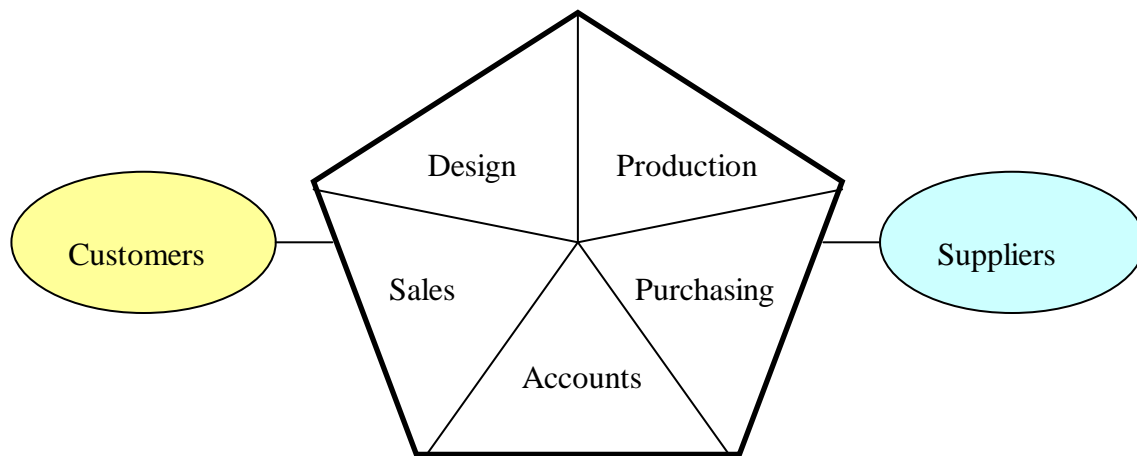


Figure 2.10: *Broad Based, Functional Decomposition of an Enterprise, based on Weston [19].*

Quite clearly, this conceptualisation of a manufacturing enterprise is at a very high level and constitutes a gross over simplification. However its simplistic nature and clarity may be used to convey the concept between people with different backgrounds and capabilities, together with facilitating reasoning about it. From developing a number of viewpoints about manufacturing enterprises we can hope to develop characterisations of different types of enterprise which can then be integrated into more

holistic representation or models of a class of enterprise or a specific enterprise instance.

Enterprise Engineering must therefore, rely upon structured approaches, and be supported by powerful tools to cover the whole system lifecycle [3]. Techniques developed through the growing fields of enterprise modelling and enterprise integration may form a powerful basis for this effort. These tools will have to have a lot of the functionality and capabilities already offered by computer-aided software engineering (CASE) tools, but need to be significantly expanded in a number of ways for specific aspects of enterprise engineering. These include resource management [151], organisational structure definition, analysis of concurrent processes, or event-driven model enactment in highly distributed environments, [152] [153] [154].

Furthermore, in relation to the discipline of Enterprise Engineering, the two notions of 'the extended enterprise' and 'the virtual enterprise' have been mooted. The extended enterprise applies an extension of Enterprise Engineering and deals with inter-enterprise integration[♦], where suppliers and manufacturers work together in more tightly coupled modes. The virtual enterprise is where an enterprise may subcontract or outsource a number of its activities and link its IT systems with those of partner businesses [3] [155]. This type of enterprise can be rapidly configured to meet windows of opportunity and is particularly applicable to SMEs where they are now able to compete in global competition to maximum advantage [156]. Browne et al [157], believe that the manufacturing function should look beyond 'the four walls of the manufacturing plant' and take a broader view, considering additional aspects such as the environment. The foundation for this suggestion is that the market place to which manufacturing businesses must now respond has changed and is comprised of:

- Business processes which cross enterprise boundaries to interface functional areas in other companies, for example, product design or manufacturing process definition [158].
- Supplier / Customer integration (People and Processes) through interchange of commercial / technical data [158].
- Ability to function effectively as links for information and product in unbuffered supply / distribution chains [158].

[♦] Inter-enterprise integration is concerned with what happens among a group of enterprises, whereas Intra-enterprise integration is concerned with what happens within a given enterprise [159].

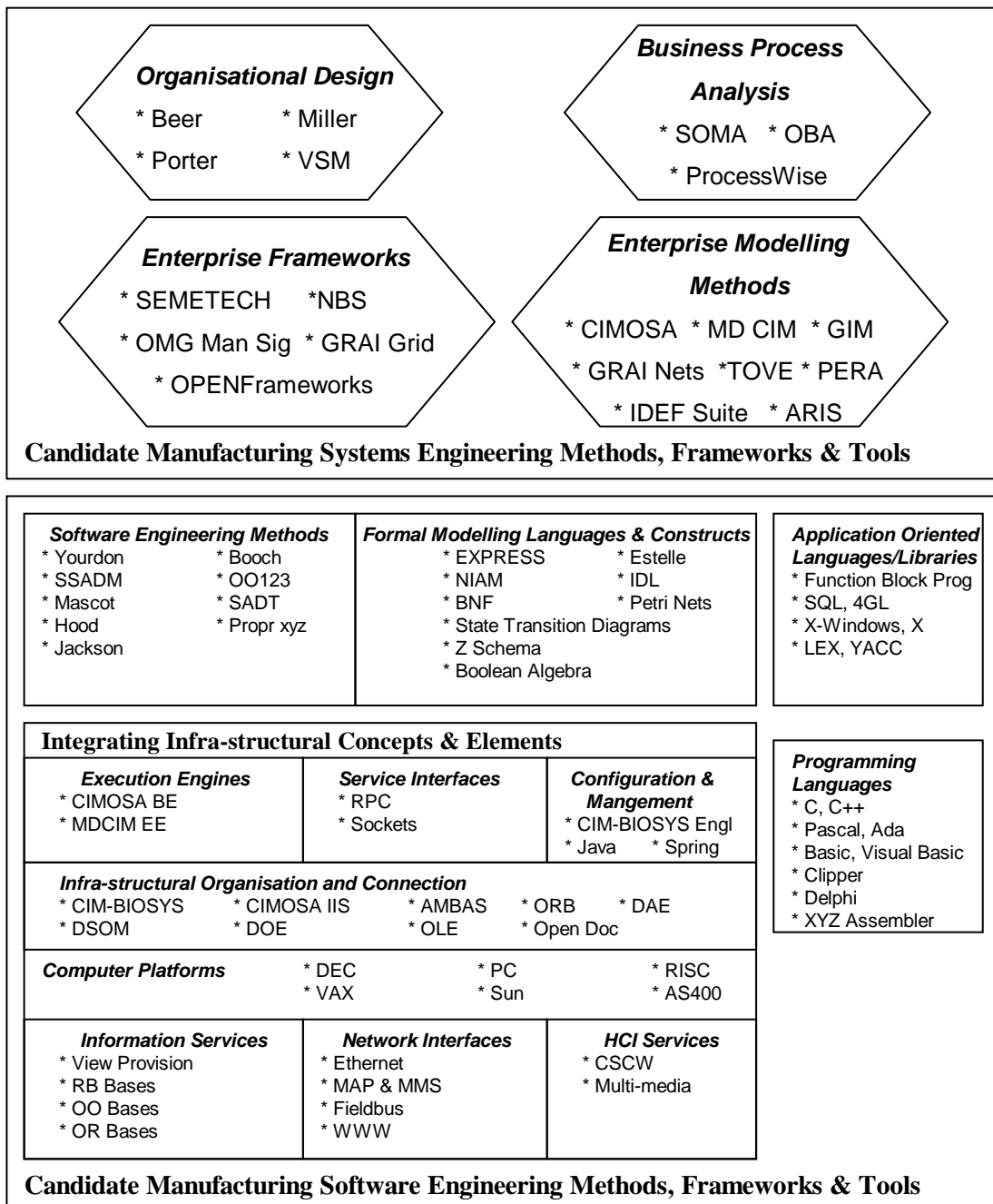


Figure 2.11: *Candidate Software Engineering Methods, Frameworks, Constructs and Tools, Weston [160].*

The capability to link the activities of a number of entities together to service customer requirement and attain profit, largely depends upon the relationships of these entities and the communications that passes between them. Agent-based software and technology [159] may provide a natural way to design and enable such manufacturing systems. Candidate engineering methods, to support Model-Driven CIM, details the breadth of concepts involved when considering Enterprise Engineering, Figure 2.11.

2.3.7 Enterprise Modelling

The implementation of BPR techniques and IT systems, together with the business restructuring operations that are present in M&A activity, are major endeavours. The provision of the most appropriate support requires the generation of specifications that capture the particular integration needs of the enterprise. In tackling this 'integration', priority has to be given to the information requirements and the process of information specification [161]. However, the development of specifications is compounded by the diversity of business strategy, organisational structure and manufacturing processes. No two enterprises can be expected to be identical, 'each having idiosyncrasies and specific functional and information needs to realise its own business goals' [162].

Despite these differences the application of enterprise modelling techniques can be used to promote good practice, provide a consensus view or road map for a group of users and add value to the enterprise [3]. 'Enterprise modelling is a generic term which covers a set of activities, and methods for various aspects of an enterprise' [163]. It is concerned with representation and analysis methods for design engineering and automation of enterprise processes at different levels of abstraction [164]. It must at least cover information, organisation, resource, and function aspects of a business entity and make possible the representation of material, information and control flows of the enterprise, either altogether or separately [165]. Enterprise models may be made of various sub-models [3]:

- Product Models
- Resource Models
- Activity Models
- Information Models
- Organisational Models
- Economic models
- Optimisation and Decision-making Models

This list is not exhaustive, as other sub-models and sub-sub models can be listed such as factory (IMPACT) [165] and manufacturing resource models [166]. The purpose of these models is to present a common understanding amid users about enterprise structures and processes, to support understanding, analysis, workflow or decision-making, usually on the basis of simulation or 'what-if' scenarios, or to control operations of the enterprise [139] [167] [168] [169] [170]. The principle characteristics that an enterprise model must have can be listed as such:

1. Represent an enterprise from multiple perspectives according to the user's needs [171].
2. Be able to answer relevant and significant questions about an enterprise [171].
3. Be accurate and complete enough to adequately support the decision making at different levels: strategic, tactical and operational [171].
4. Include access to past decision rationales, ability to survey the current enterprise wide state and deduction methods for formulating business decisions [171].
5. Be executable or be easily transferred into executable form(s) [171].

If appropriately implemented into an enterprise model, these attributes should enable the model to effectively support the realisation of contemporary enterprise activities and become a significant factor in the accomplishment of effective enterprise integration [172]. 'A modelling methodology refers to a class of similar methods, where a method is an organised, single purpose discipline of practice' [173]. Ross proposes that any modelling technique should be based upon four constituents, [174]:

- | | |
|--|---------------------|
| 1. Definition of the purpose, | 3. Viewpoint, and |
| 2. Range or Domain (<i>Universe of Discourse</i>), | 4. Detailing level. |

Vernadat [3] (*No. 1-8*) together with Ward and Mellor [175] (*No. 9-13*), extended these essential theories to include the additional 13 principles of:

- | | |
|--|---------------------------------------|
| 1. Separation of concerns | 8. Conformity |
| 2. Functional decomposition | 9. Model Visualisation |
| 3. Modularity | 10. Simplicity versus Design Adequacy |
| 4. Model Genericity | 11. Management of Complexity |
| 5. Reuseability | 12. Rigor of Representation |
| 6. Separation of Behaviour & Functionality | 13. Separation of Data and Control |
| 7. Process and Resource Decoupling | |

It is noted, by Vernadat [3] that very few modelling methodologies and techniques for enterprise modelling correctly address all of these principles. Basic methods have been previously developed to assist in the modelling of different information and system aspects, but these are generally limited to particular areas of modelling and were not

initially related to the notion of manufacturing enterprises. Molina [172] has classified these general methodologies into four groups:

1. **Information / Data Modelling Methods:** These allow the description of the information structure relevant for a system in an implementation independent format named a data model [176]. Data modelling methods have been generally derived as aids to database design. As such they tend to support the modelling of entities and the relationships between them. Information modelling can be viewed as an offshoot from data modelling whose goal is to characterise real world objects as completely and realistically as possible [177]. Information modelling is related to the identification, representation and composition of data, information and knowledge that describes a real object or objects [178]. The difference between these two types of modelling is that the data model created can be computer processed whereas the information model cannot [179]. These types of modelling method include Data Flow Diagrams (DFDs) [180], Entity Relationship (ER) Diagrams [181], IDEF (Integrated computer-aided manufacturing DEFINition methodology) and IDEF1x [182], NIAM (Nijssen's Information Analysis Modelling) [183], Dependency Diagrams [184] and Express [185].
2. **Process Modelling Methods:** These provide a description of a system's functions, through the process of function decomposition and categorisation of the relations between them [178]. A process model depicts how an individual activity is performed in multi-staged functional levels and what constraints are associated to them. Process modelling represents how an entity does something in terms of strategies, rules and constraints [186]. Typical Process modelling methods include IDEF0, IDEF3 [187] [188] [189] and SAMM (Systematic Activity Modelling Method) [190] [191].
3. **Behaviour Modelling Methods:** These techniques are concerned with the dynamic behaviour of systems, i.e. what happens in relation to the element of time? [192]. All entities have a state in time, execute an operation and exhibit some performance. Modelling behaviour in this way allows the representation of time

dependencies (concurrency, sequence, parallelism) operation execution and performance [193]. IDEF2 [187] and Petri Nets [194] [195] can be seen as common behaviour modelling methods.

4. **Hybrid Modelling Methods:** This group of methods allows a system to be described by modelling data, activity and behaviour in combination. The objective is to characterise real world objects as completely and realistically as possible. The integration of different modelling dimensions in hybrid methods enables the construction of models, which can represent a truer reflection of reality. These methods include Semantic Nets [196], Conceptual Graphs [197] [198] and Object Orientation Methods [199] [200].

This review does not cover all the possible modelling methodologies available, but the more popular ones used in the community of IT systems which support manufacturing environments. Vernadat [3] separates different types of enterprise modelling into function-based or process-based methodologies. It is expressed that the dominant method in recent times has been the function-based approach. This utilises that the central concept of function which is made recursive to be used at all levels of modelling and at any depth of the model. This is typically the case with IDEF and SADT (Structured Analysis and Design Technique) [174] [201] techniques. The main two problems which this functional approach are proposed as:

- Over-generalisation of the resulting model due to lack of semantic description power, resulting from the use of only one basic construct, and
- Strict hierarchical functional decomposition, which tend to map the organisational boundaries of the enterprise and may lead to the creation or re-creation of so-called 'island of automation' [3].

The application of process-based modelling is said to be a more powerful and unconstrained practice of approaching enterprise modelling, that can encompass attributes associated to the temporal nature of processes. With the concept of process as a way of chaining activities, core processes are modelled entirely from their start to end on the basis of their flow of control, flow of materials and flow of information,

without any consideration of organisational boundaries. The enterprise modelling process can be seen in Figure 2.12.

This process overview proposes the utilisation of ontologies. An ontology can be seen as a formal description of entities and their properties. It forms a shared terminology for the objects to be communicated in a given domain, along with the definitions of the meaning of each of the terms employed. An enterprise ontology therefore, can be 'viewed as a collection of terms and definitions relevant to business enterprises' [203]. The use of ontologies for enterprise modelling has been suggested in the TOVE (Toronto Virtual Enterprise) project [204] and the University of Edinburgh's Enterprise Project [205]. IDEF4 also provides support for ontology definition [206].

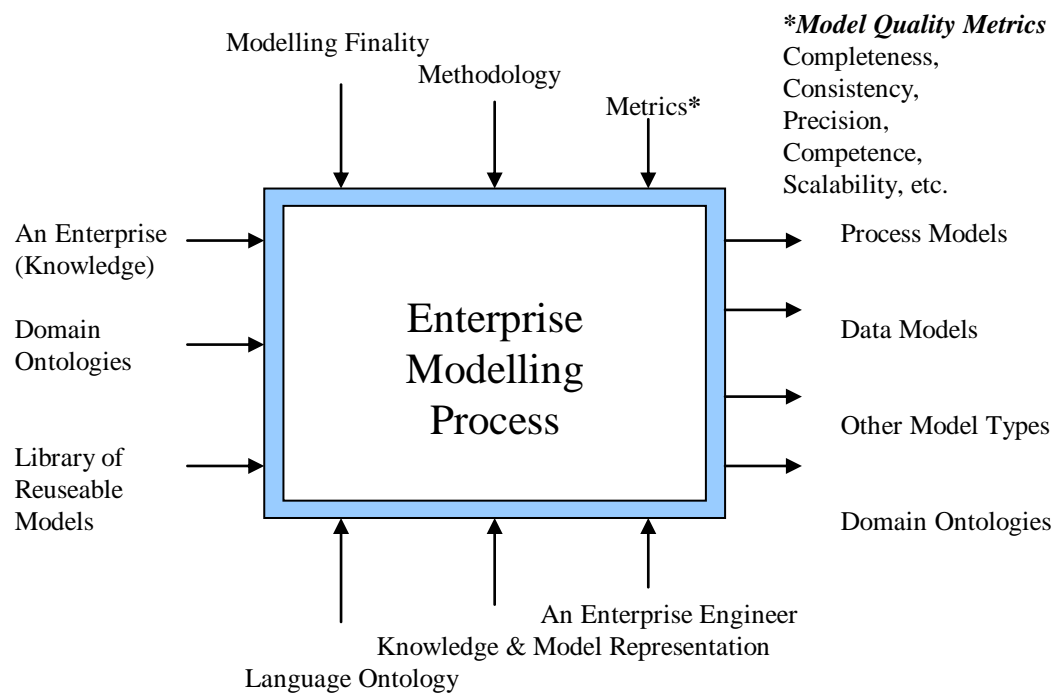


Figure 2.12: *Enterprise Modelling Process Overview, Petrie [202].*

Since the 1980s, previous IT systems modelling techniques have matured into what we now class as suitable enterprise modelling approaches (reference models, architectures and frameworks). These include:

- IDEF (Integrated computer-aided manufacturing DEFinition methodology) suite of methods [207],
- PERA (Purdue Enterprise Reference Architecture) [208] [209],

- CIMOSA (Computer Integrated Manufacturing Open System Architecture) [164] [210],
- GRAI-GIM (Graphes a Resultants et Activities Interrelies - GRAI IDEF0 Merise) methodology [211] [212] [213],
- ARIS (Architecture for Integrated Information Systems) [214] [215] [216],
- GERAM (Generic Enterprise Reference Architecture Methodology) [144] [217] [218].

Each of these architectures has their own strengths and weaknesses in supporting the life-cycle of manufacturing enterprises, to the extent that key requirements for enterprise integration have been formalised by European and World Standard Bodies, e.g. CEN TC 310 [219] and IFAC/IFIP's GERAM [144] respectively. In addition to these architectures, other researchers have developed their own frameworks, for example: IEM (Integrated Enterprise Modelling) [220], TOVE [221] and EMS (Enterprise Modelling System) [222]. Of these techniques, only limited influence has been carried through to SMEs [223] [224] [225] [226] [227]. Extensive comparisons of all these methodologies can be found in 'Enterprise Modelling and Integration' [3], 'Architectures for Enterprise Integration' [228], together with the additional literature surveyed in this section.

The terms, architecture and framework have been ambiguously used within the manufacturing environment to denote reference models that assist in the development of integrated systems during different life-cycle phases of an enterprise. The general reason for conceptualising various aspects of enterprises in terms of models is to supply an explicit method for understanding, controlling and monitoring of the enterprise [229]. Mayer and Painter [230] have considered the differences between an architecture and framework. An architecture relates more to the IT systems, in terms of operating systems, databases, networks and integration utilities required for enterprise integration, whereas a framework refers to an organised representation of characterised situation types that occur during an information system life-cycle.

Many of the modelling architectures were conceived for the design and implementation of CIM systems. These have the foundation upon describing the invariant relationships and elements, which the individual CIM system was conceptually composed of, in addition to their functionality [207]. Moreover, these models also described specifications that could be transformed or enacted into working systems. The impetus for developing enterprise reference architectures is based upon

the premise, that a large part of an integrated project is common to every type of enterprise, thus the similarity can be captured, standardised and used. Generally accepted architectures can be supported by reference models and modelling products which can make the entire modelling effort efficient in time and cost [231].

2.3.8 Enterprise Integration

Integration issues arise in all parts of a manufacturing enterprise. This is because the high levels of complexity in an enterprise require the use of decomposition processes to yield understandable and implementable sub-systems. Then having broken down things into understandable parts, integration processes are needed to achieve coherent and co-ordinated enterprise behaviours [17]. Enterprise integration can be considered to be a technologically driven process and improved integration techniques have become available over time. Themes such as CIM [21] [27] [162] [232], Integrated Manufacturing Systems (IMS) [233] and Enterprise Integration [3] are now easily recognised throughout the manufacturing community. Integration can be viewed as the process of bringing together isolated bodies to form a whole structure, removing islands of computerisation that are generated from Tayloristic emphasis on specialisation and distinct division of responsibility [161]. Deasley [234] presents other useful statements that have a home, at present, in modern manufacturing. These are holistics, society, change, process and system.

HOLISTICS - Implies we talk of total business involving the company, its suppliers and customers [234].

SOCIETY - Implies hierarchy and structure; we are currently altering our structures by flattening the hierarchies [234].

CHANGE - Implies movement between states, acknowledging the hurdles to this and devising a route to negotiate them [234].

PROCESS - Derives from chemical engineers and refers to something running across all aspects of manufacture, akin to task force and concurrent engineering teams [234].

SYSTEM - Whether in the natural or man-made environment, implies an entity comprising parts which seek survival and displays properties other than those deriving from the parts; the emergent properties of the whole which really are greater than the sum of the properties of the constituents [234].

The topic of integration is complex and difficult to discuss comprehensively as it brings together many theories from various disciplines. Integration may be viewed as a way of life, work and education. Each of these theories, associated methods and tools may help to develop and support manufacturing enterprises both now and in the future.

Today, enterprises are tending towards forming fully integrated business environments. These environments are trying to operate as an extended enterprise with their suppliers and customers, all sharing information to realise customer requirements and manufacturing possibilities quickly [236]. The adhocracy as developed by Mintzberg [237], exemplifies all the features of a modern integrated process driven system. An adhocracy is described as a highly innovative organisation that brings together professionals from different spheres of influences, which function as expert project teams. Similarly, Warnecke [25] conceived the 'fractal factory'. It has a repeating group structure where key personnel span two individual groups to provide direction and information exchange. This type of structure is very dynamic and again requires little central planning whereas, many current CIM systems are becoming too inflexible because they have been developed to satisfy all of an enterprises' business processes.

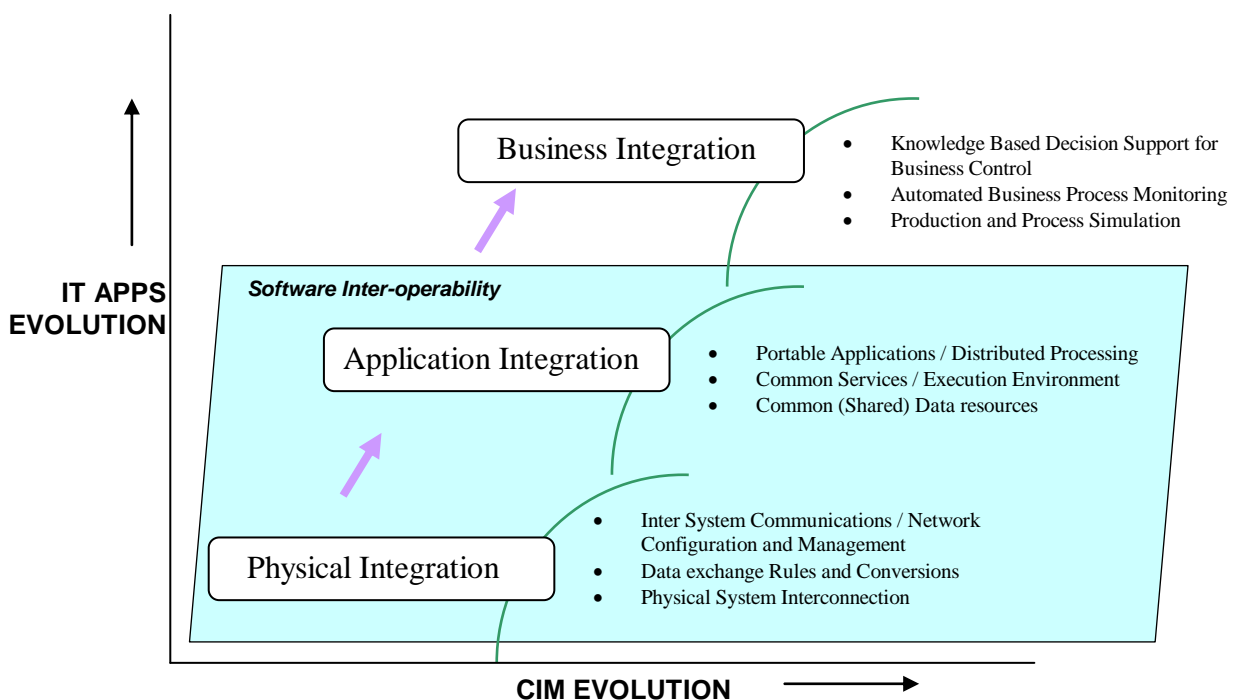


Figure 2.13: *Integration Levels in the Manufacturing Enterprise, AMICE [165].*

The primary function of enterprise integration is said to be the development of solutions and computer based tools that facilitate co-ordination of work and information flow across organisational boundaries [3]. This type of integration will occur when there is an improvement in the task-level interactions among, businesses, departments, services and people. This however, cannot be simply achieved by connecting computers [17] [164] [238]. The AMICE CIMOSA consortium [239] classified integration for the enterprise within the following three levels, Figure 2.13.

Kosanke et al [138], go further to add the higher level of enterprise integration and the utilisation of organisation networks, to the CIM/IT application evolution process.

Business Integration: At this level, enterprise goals and strategic business issues are considered. Despite the technological advances offered by contemporary business applications, computer hardware and networks, it is important to have fast means of analysing, designing simulating and implementing, new functions and operations. These may be integrated with production control and monitoring as defined by the CIMOSA architecture [164] [240].

Application Integration: Integration at this level is defined as concerning inter-operation between applications to facilitate data sharing and information exchange. It can be said to be the 'making use of distributed software for industrial automation overcoming: hardware, operating systems, networks, programming languages and database heterogeneity. Standard, portable packets of software (middleware) that provide a common Application Program Interface (API) can be utilised. Distributed platforms like OSF/DCE (Open Software Foundation/Distributed Computing Environment) [241] and OMG/CORBA (Object Management Group/Common Object Request Broker Architecture) [242] support this concept.

Physical Integration: This is mainly concerned with data and inter-process communication issues. It expects this level of integration to be provided by current IT standards and concepts. Industrial network standard such as MAP (Manufacturing Automation Protocol) [243] and CNMA (Communication Networks for Manufacturing Application) [244] can be employed. Despite many standardisation efforts, it is hard to promote physical systems integration at all enterprise levels [239].

Within the scope of enterprise integration, the term 'software inter-operability' has been used to describe the ability of separate software applications to functionally interact to meet business goals. As such, software inter-operability is targeted at the physical and application integration levels of enterprise-wide integration [162].

As discussed in the previous thesis section 2.3.7, enterprise modelling is clearly a prerequisite for enterprise integration. The 1980's reference to enterprise integration as, the 'integration of data and information', has been superseded by the primary concern of business process co-ordination, Norrie et al [245]. Nowadays, business processes, along with their corresponding objects, methods, resources and intelligence need to be formalised in order that they can be effectively integrated or computer controlled. If an agent called system A executing a given business process wants to 'talk', i.e. interact in the form of a conversation, with an agent called system B executing another business process, there will be the requirement of two fundamental components [3].

1. An **integration platform** and its **integrating infrastructure (IIS)**, i.e. some support (hardware and software) to allow communication between system A and system B in the form of a flow of information objects, and
2. An **enterprise model**, or common semantic referential, used to ensure that when system A refers to concept C, system B has the same understanding of concept C as system A.

The enterprise model will act as the semantic unification tool to share knowledge between the two systems and could be described in the form of ontologies [246]. The IIS is a systems integration enabling tool that can allow computer programs and applications to 'functionally interact'. The main IIS goal is to, structure, service and where possible, reduce the complexity of inter-connection between different software systems. PlantWorks/DAE (Distributed Automation Edition), Workstream/Base Star and Industrial Precision Tools (IPT) from IBM, Digital and Hewlett Packard respectively, can act as a backbone for enterprise-wide integration [162]. Figure 2.14 shows how software application inter-connection can be facilitated by an IIS.

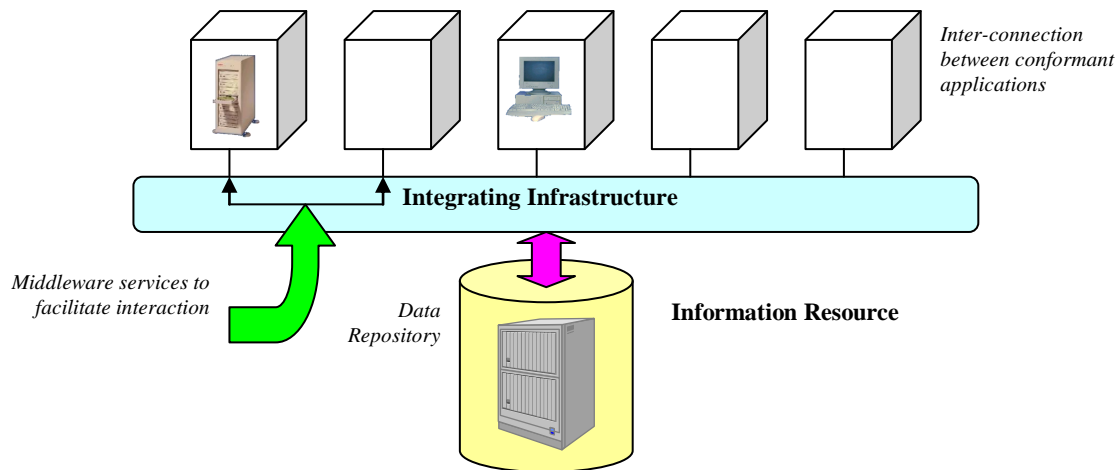


Figure 2.14: *Inter-connection via an Integrating Infrastructure, Singh [162].*

The primary motivation for the utilisation of enterprise integration, encompassing an IIS, is to facilitate 'true' information exchange (not necessarily data) within or external to the enterprise [3]. An IIS should also, support open systems, provide 'plug and play' connectivity and can be tasked with resolving differences in a physical system relating to heterogeneity, distribution and data fragmentation. An IIS can be supported by software tools to reduce complexity and middleware which is typically composed of APIs. Middleware services can be categorised into five groups, Message Oriented Middleware (MOM), Remote Procedure Call (RPC), Data Access, Distributed Transaction Processing (DTP) and Object Request Broker (ORB) [162]. According to CIMOSA an IIS for manufacturing enterprises should exhibit the following characteristics [163]:

- | | |
|---|----------------------|
| a) Distribution | f) Reliability |
| b) Openness | g) Security |
| c) Application portability and connectivity | h) Performance |
| d) Application Inter-operability | i) Migration support |
| e) Conformance / compliance to standards | |

The first four properties relate to the rational behind IIS. Contemporary manufacturing enterprises are typically global in outlook and openness is mandatory for developing trust and the effective management of change. Application, portability, connectivity

and inter-operability are pre-requisites for the ease at which applications can communicate with each other and run on different hardware / software platforms [3].

Previous research at Loughborough University has led to the development of the CIM-BIOSYS (Computer Integrated Manufacturing - Building Integrated Open Systems) IIS [247] [248]. This was developed to demonstrate a variety of IIS 'proof-of-concept' and 'live industrial' integrated systems. It exists as a complete software environment for developing and running flexibly integrated applications in a systematic way. It embodies low level integration services to facilitate data management, access, manipulation and presentation, and support inter-process communication amongst functional components. Further work on IIS has been undertaken using CIMOSA [160] [249], CCE (CIME Computing Environment)-CNMA [244] [250], AMBAS (Adaptive Methods Base Shell) [251], together with PACT (Palo Alto Collaborative Testbed) and SHADE (for Shared Dependency Engineering) [252].

Whilst it is possible to draw knowledge and experience from industrial initiatives on enterprise integration, such as AIT (Advanced Information Technology), SEMETACH, PRIMA, POSC (Petrochemical Open Software Corporation) and NIIIP (National Industrial Information Infrastructure Protocol) [3], the CEN/TC 310/WG1 standardisation group on Advanced Manufacturing Technologies on Systems Architecture should be a primary research focus. It has been mandated to review national, European and international initiative for Enterprise Model Execution and Integration Services (EMEIS). This is required for the execution of manufacturing enterprise models as defined by the ENV 40 003 [157] and is ongoing [253] [254].

A final aspect of the, Enterprise Engineering concept is the overall methodology that is to be employed. Uppington and Bernus [255] suggest that an IDEF0 process model can be utilised for assessing the necessity of enterprise change. Edwards et al [141], propose a top down bottom up approach using the CIMOSA function view, and Kim et al [140] describe a completely integrated methodology. Enterprise Engineering is still only in its infancy, but it can be said to offer hope and support for the new enterprise paradigms of extendedness, virtuality and agility [143].

2.3.9 Supply Chain Management

During the last few years business focus has shifted from factory level to enterprise level due to the increasing global presence of enterprises [34] [256]. High proportions of manufacturing enterprises are now organised as networks of manufacturing, assembly and distribution sites, which may be scattered around the world. These networks, which we refer to as 'Supply Chains' affect crucially both customer service and the total cost to the customer of products and services [257]. Supply Chain Management (SCM) is now recognised as one of the best means by which manufacturing enterprises can make instant improvements to their business strategies [258] and can be easily related to a concept comprising of a stream of activities which are linked together, Figure 2.15. Kruse [259] defines SCM as '*The process of developing and co-ordinating a sequence of business relationships, in order to deliver optimum end-customer value, whilst satisfying stakeholder requirements*'.

The success and failure of SCM is ultimately determined in the marketplace by the end customer. Getting the correct product, at the right price, at the agreed time to the customer is not only the route to competitive advantage but also the key to survival. Supply chain performance improvement initiatives strive to match supply and demand thereby driving down costs simultaneously with improving customer delight [260]. First step changes, to optimising enterprise logistic processes have relied upon concepts such as BPR, JIT and TQM to become faster and more agile. But the potential improvement possibility of these approaches is only limited. This is because most of the business processes concentrated upon, within the enterprise, cover only a small proportion of the whole value chain. The implementation of SCM techniques, as a second step, should lead to enhanced cost saving opportunities as the whole supply chain can be considered and optimised [261] [262]. When applying SCM principles, primary factors to consider are supply chain goals and performance measurement?

- How can we get our suppliers to reduce costs (not prices) and increase flexibility and customer service? [263].
- How can we get suppliers to think in terms of the benefits of change to themselves and their customers? [263].

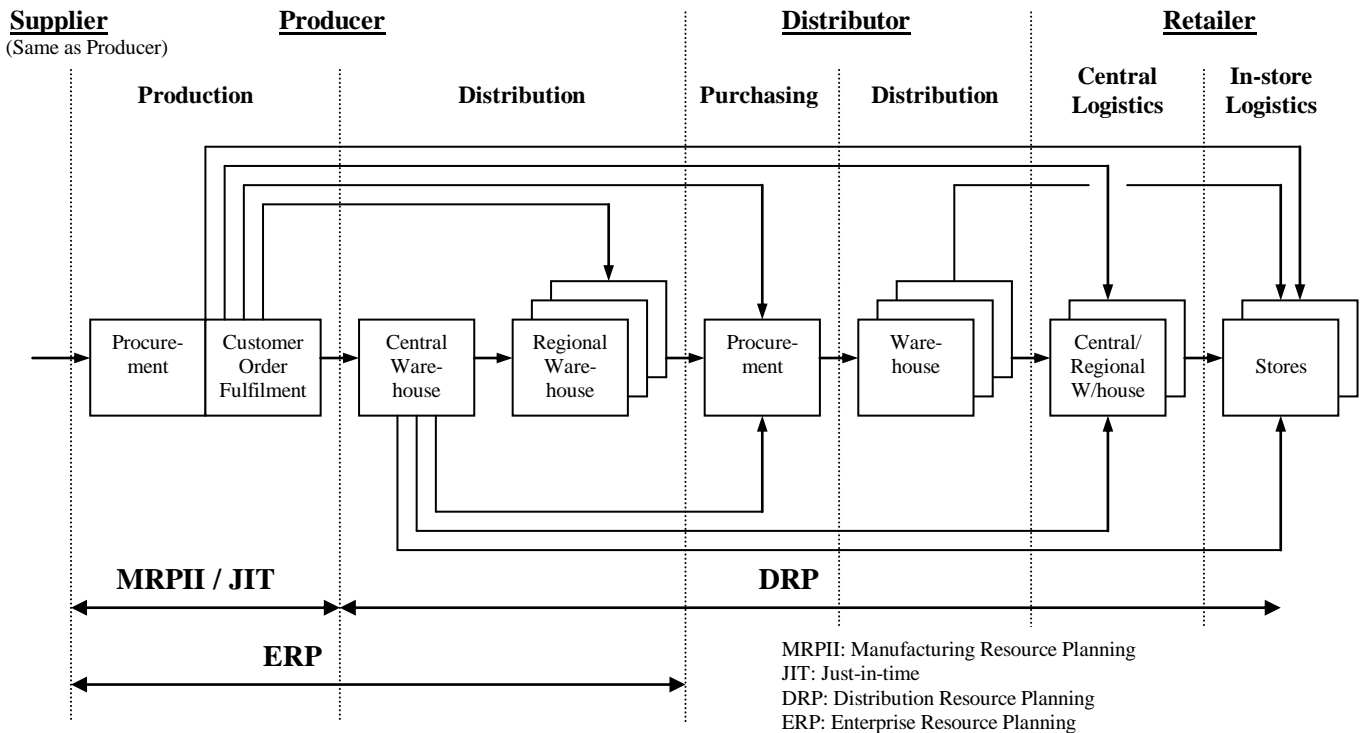


Figure 2.15: *Total Supply Chain Elements, Kruse [259].*

According to Bowersox [264], the objectives of performance measurement and controlling activities in logistics are to track performance against operating plans and to identify opportunities for efficiency and effectiveness. Four levels of measurement are proposed: Direction, Variation, Decision and Policy. Direction measurement applies to the execution of the operational plan; variation measurement is related to accumulated deviations from plan; decision measurement is concerned with modifications to the operational plan and policy measurement involves the changes in business objectives. It is further argued [265], that an ideal measurement system should incorporate three elements that provide accurate and timely direction for the enterprise. These are cost/service reconciliation, dynamic knowledge-based reporting and exception-based reporting. The ENAPS (European Network of Advanced Performance Studies) consortium has presented a model for measuring logistics processes especially in aerospace, automotive and electronics industries [256] [265]. Van Amstel and D'Hert [266] provide a four-level model, which is very similar to Bowersox.

The concept of the supply chain gives rise to the phenomenon formulated by Forrester [267] and Burbidge [268] as the 'law of industrial dynamics' or 'bullwhip

effect', where true market demand is distorted and amplified as orders are passed from one level to the next, along the chain. Changes in demand result in policies that counteract the efforts of effective logistics management to reduce stock, improve product quality, minimise the total cost of operations and procurement, ensure adequate levels of customer service and minimise variance in material flow. The most demanding task of SCM is to establish a methodology whereby this 'law' may be suppressed or minimised [269]. Some of the problems associated with this are:

- Scheduling difficulties, particularly in bottleneck plants [270].
- Difficulties in managing labour requirements: at times there is a need for overtime and at other times personnel are idle [270].
- Problems controlling inventory levels and resulting warehouse requirements [270].
- Excessive administrative effort and fire-fighting [270].

It has been found that reducing inventory by eliminating the 'bullwhip' effect can give a 10-30% increase in profitability [271].

There are many new approaches to SCM, additional work includes, Hieber et al's Network Diagnosis System [261] which aims to provide fault-finding tools for evaluating and optimising the performance of supply networks. The LEAP Project at Cardiff Business School [272] is centred upon the premise that considerable productivity gains are to be made from mapping, and then managing a supply chain as an integrated whole. The Supply Chain Council [273] have undertaken wider research around SCM concepts to develop a Supply Chain Operations Reference model (SCOR) to enable enterprises to better understand and improve their own supply chains. Supply chains can now be modelled with enterprise engineering techniques [157] [274], simulated [275] and applied to SMEs [276]. Business applications such as ERP and APS (Advanced Planning and Scheduling) together with data sharing techniques of the Internet, EDI (Electronic Data Interchange, FTP (File Transfer Protocol) and XML (Extensible Markup Language) can underpin SCM methodologies [277] [278] [279].

The fundamental foundations for SCM can be seen simply as three views of management concerns, namely: relationship, information and cash flow [280]. Supply

chains end with customers, but this is not necessarily the end of a product's life. The product may still be re-cycled or re-used.

2.3.10 Critique - Management Concepts

The overview of the management concepts described within this sub-section, to a certain degree, represents a history of consultancy and academic 'bandwagons' (e.g. BPR) that have been touted to the manufacturing community as the next panacea for curing all management ills. Whilst it is acknowledged that each technique has its own merits and undoubted implementation successes, it becomes visible that a common issue is the requirement of a clear business strategy, with well defined goals and time-scales, that focus upon the contemporary business imperatives of quality, speed and price.

The applications of these techniques have been typically focussed on and considered viable for large manufacturing enterprises, which have stable product ranges, considerable budgets and suitable resource provision. However, the suitability of these concepts for application to SMEs, which operate more complex and dynamic manufacturing strategies need to be further and empirically tested. Whilst contemporary research on enterprise engineering outwardly offers fundamental advantages over previous BPR concepts and techniques, it has only ever been applied within larger organisations. Currently, there still exists a multitude of disparate models, architectures and techniques which have yet to be combined into one overall holistic methodology that could be applied successfully to an SME. Furthermore, the complexity of contemporary enterprise engineering techniques (e.g. CIMOSA) look to easily fall outside the experience and understanding which SMEs may reasonably hold.

SMEs are now regularly involved in M&A activity and there is no evident reason why this should cease. The focus of larger organisations to attain improved control over their supply chain appears to be a key factor in meeting global customer requirements and achieving improved economies of scope and efficiency. Another central theme running through the IT perspective of manufacturing within this context can be viewed as integration and co-ordination. Achieving this, amongst a backdrop of individual and isolated networks, standards and systems can be viewed as the real challenge.

2.4 Manufacturing Techniques

Success is much harder to analyse than failure. When things go wrong in air traffic control or a chemical plant, it is usually possible to deduce what the cause was and resolve to avoid those things in future. But when things go right in a manufacturing enterprise, it may be difficult to know why? Which factors were important to the success and which were a hindrance? Was the success due to products, technology, skill or just luck? [281]. The possibility of being able to look into a crystal ball to assess the likely impact of any action is very attractive. The search for the manufacturing strategy and paradigms of the near future that will bring competitive advantage and sustain success is of compulsive interest to the manufacturing industry. This literature section utilises the term 'Manufacturing Techniques' as an all-encompassing term under which to group current manufacturing strategies, associated production control approaches and implementation methodologies.

2.4.1 Manufacturing Strategy

An effective manufacturing strategy is a prerequisite for any aspiring global enterprise and should be related to the current world economic environment. For the larger part of this century the development of the manufacturing industry and patterns of global trade have evolved relatively slowly, in spite of two major world wars and in such a periods of slow growth there has been little formal interest in manufacturing strategy and paradigms [282]. However, the opposite is now true and there is a strong focus for governments and industry to provide stability for the future and to put policies and actions into place which will underpin success. Recent, UK [52] and US [283] government initiatives have produced proposal documents to present the Establishment's view of reinvigorating the national economy. Moreover, it is not possible to entirely separate the content of a manufacturing paradigm from the context in which it was generated. PEST influences apply and vary considerably throughout the world and time.

Additionally, a highly simplistic concept has been proposed, where the industrial development of a nation can be placed upon a continuum of economic / industrial development. Four stages of this continuum have been identified by McKinsey [284].

- **Commodity Product Supplier:** Making and supplying standard commodity items, such as nuts, bolts, basic consumer items.
- **Component Suppliers:** Producing components and assemblies, such as motorcars, automotive assemblies, standard computer configurations and peripherals.
- **Systems Suppliers:** Where systems are seen very broadly as complex end products, such as capital goods, specialist high-tech equipment, machine tools, IT systems, bridges, etc.
- **Product Innovation Suppliers:** Offering new technology and innovative products ahead of other suppliers.

The premise of Williams' [279] is that nations will progress through the industrial value progression as they develop industrially. Based upon this line of argument the UK has been classed as a predominately higher-tier component supplier, whereas Japan and Germany have been classified as innovators [285]. The positions of selected nations can be seen in Figure 2.16.

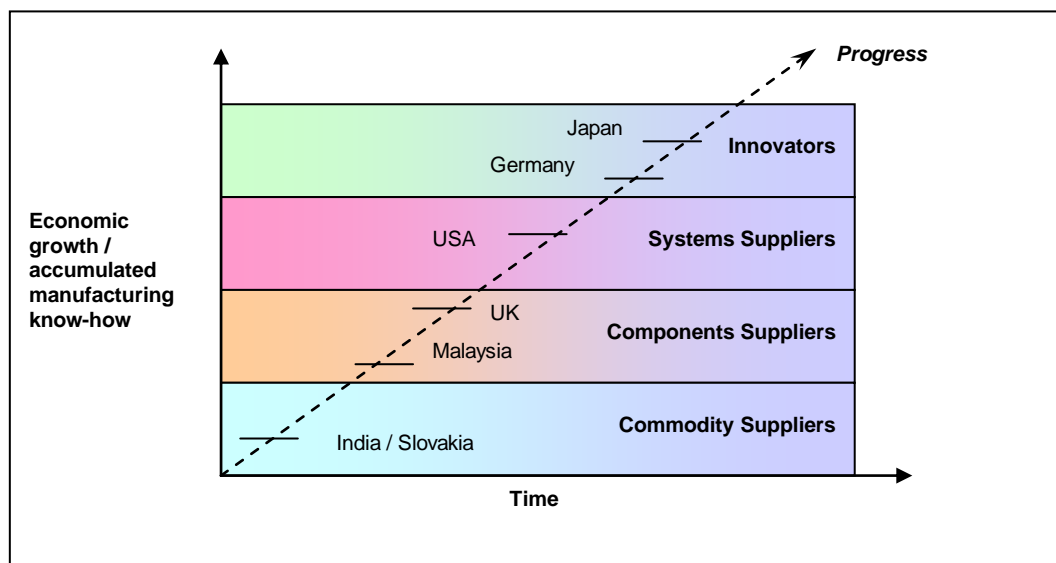


Figure 2.16: *Industrial Position of Selected Nations, Kruse [285].*

Kruse proposes 'The Value Portfolio' concept [285]. This is akin to Porter's Value Chain [286] and suggests that customer value can be determined by five key factors: product specification, cost, quality, flexibility and service. Similarly, Hill [287] argues that in each market in which an enterprise operates it should identify those criteria that win orders against competition. His criteria are price, delivery, quality, product design

and variety. Brand perception maybe another factor, where the general desirability of a product or a perception of its superiority might override the more rational factors of The Value Portfolio and Hill's order winners.

Manufacturing enterprises need to understand which Value Portfolio its customers require versus which Value Portfolio a country may deliver. Porter [286] considers manufacturing to be only a constituent part of the overall value chain of an enterprise. Its level of importance may be changed in different enterprises, but it is only one cog in the wheel of a successful business.

Strategy is a tool of vigilance and foresight, a primary key to surviving the transformation widespread global change brings, and if necessary, transforming oneself [135]. Strategy is about operating in the future as well as today and conventionally addresses a time frame of years not necessarily weeks or months. 'Manufacturing strategy is a critical part of an overall business strategy. One is not subordinate to the other, nor are they independent' [288]. Swamidass and Newell [289] define manufacturing strategy as 'The effective use of manufacturing strengths as a competitive weapon for the achievement of business and corporate goals'. Manufacturing strengths are developed and sustained by a 'pattern of decisions' [290] as initially proposed by Mintzberg and Waters [291]. These decisions are then made in a number of distinct areas, which encompass manufacturing strategy and are aimed at achieving manufacturing goals that align with enterprise and business goals.

It is now generally regarded that researchers at Harvard in the 1940s and 1950s [292] developed the foundations of what is referred to as manufacturing strategy. Skinner then disseminated knowledge about manufacturing strategy in what may be considered to be two key works. Firstly, he identified the absence of manufacturing in the corporate planning process [293] and then, secondly he developed the concept of focus and of internal as well as external consistency [294]. Cheng and Musaphir [295] suggest that 'A manufacturing strategy should be tailor-made to accommodate the idiosyncrasies of a given enterprise'. However, there are so many common issues present in the formulation of a manufacturing strategy that it may only be possible to generate a useful, general purpose, process to enterprise management thinking in this area [296].

Numerous articles dealing with the practice and development of manufacturing strategy have been published over the years. Sweeney and Szwejczewski [297] have studied the UK engineering industry with relation to manufacturing strategy and performance, Chenhall [298] has undertaken an empirical study that relates manufacturing flexibility strategies to organisational performance and White [299] has undertaken a survey and developed a taxonomy of strategy-related performance measures for manufacturing.

A foundation of manufacturing strategy is the conceptual framework that organises the thought processes of the managers involved in the development and articulation of that strategy. Wheelwright [300] suggests a framework, which consists of a brief description of the nine major categories of manufacturing strategic decision-making and an identification of the four manufacturing performance measures that address the objectives of manufacturing strategy.

Strategic Decisions Categories

1. Facilities
2. Capacity
3. Vertical Integration
4. Processes / Technologies
5. Scope / New Products
6. Human Resource
7. Quality Management
8. Manufacturing Infra-structure
9. Vendor Relation

Performance Measures

1. Cost
2. Quality
3. Delivery
4. Flexibility

Important trade-offs have to be made amongst these categories and measures when formulating manufacturing strategy. It is not possible to excel in all of them simultaneously. Defining the primary manufacturing competitive thrusts, aligned to enterprise business goals and the tasks to accomplish them is at the heart of manufacturing strategy design [295]. The manufacturing continuum, described by Weston [19], provides another viewpoint of the modern day shift of manufacturing focus, Figure 2.17.

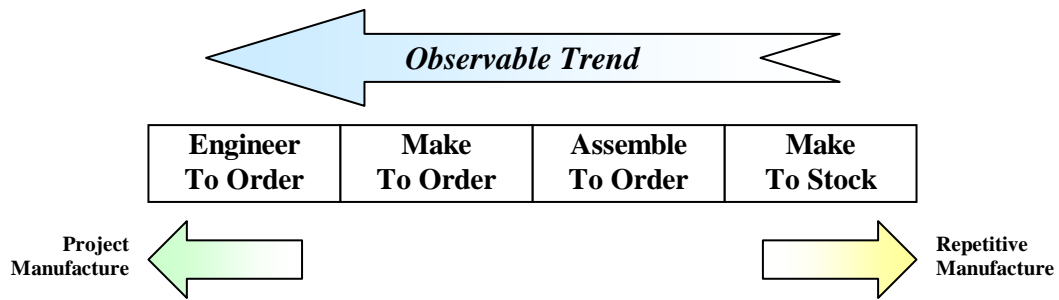


Figure 2.17: *Manufacturing Continuum Decomposition, Weston [19].*

However, in some markets, product specification may be adequate enough to remain fixed over long periods, whereas in others the life-cycle of products may be extremely short and correspond to that of the production cycle. This more rapid construction is typical of certain configure-to-order, (or so-called contract) manufacturing environments. Joseph [301] provides a detailed overview of the manufacturing strategy formulation process. Mills et al further considered this process, utilising a contingency approach [302] and then incorporating a learning perspective [303]. Their manufacturing strategy process framework can be viewed in Figure 2.18.

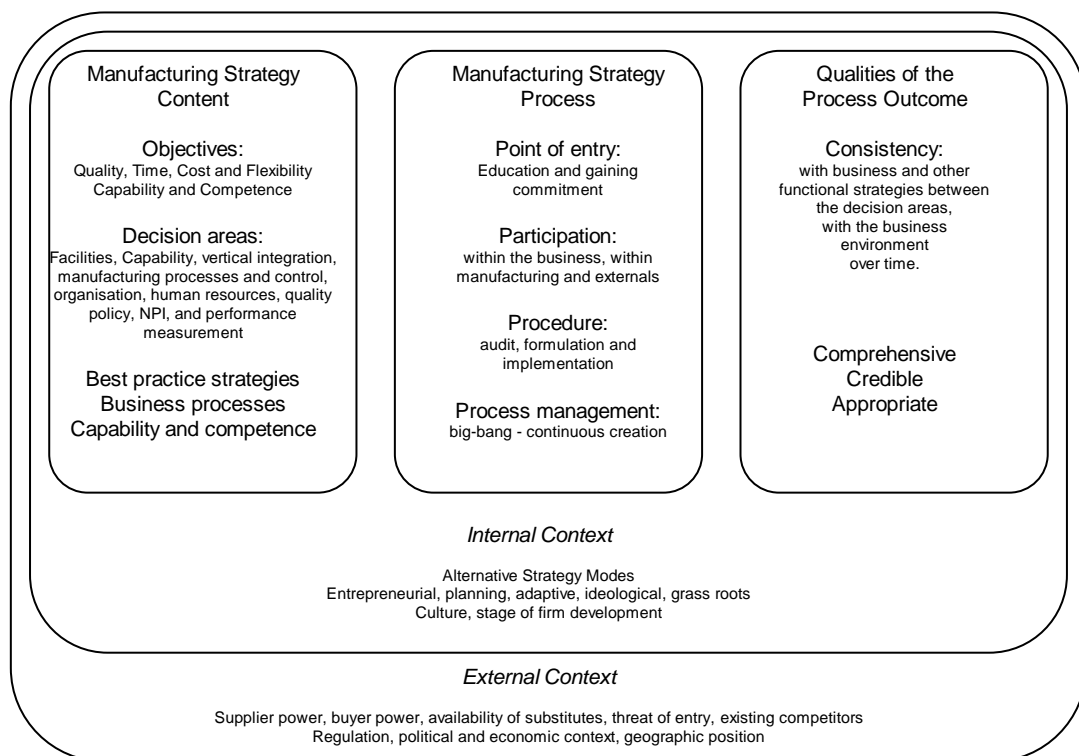


Figure 2.18: *The Manufacturing Strategy Process Framework, Mills et al [305].*

How can we ascertain what a manufacturing strategy actually is? Is it Agile or Lean Production, Virtual, Holonic, JIT or TQM? How do these radical concepts, that can fall under the newly coined term of 'New Wave Manufacturing (NWM)' [88], align with Skinner's notions of manufacturing objectives and strategic decision areas? These questions are currently concerning manufacturing strategy researchers [307].

Rhodes [288] comments that there is only a small amount of strategic thinking in SMEs. An UK survey [304] further supports this notion, where it is commented that uni-dimensional strategies such as MRPII, JIT and TQM were the most regular descriptions of SME manufacturing strategy. Often previous best practice strategies, such as MRP or advanced manufacturing technology, did not live up to expectations. Wainwright and Leonard [305] provide a process model for SME manufacturing strategy formulation, based upon a novel combination of AMBITE (Advanced Manufacturing Business Implementation Tool for Europe) [306], GRAI and IDEF methodologies.

The goal of NWM strategies is often expressed as a set of absolutes, such as the 'five zeros'. These comprise: zero paper, zero inventory, zero downtime, zero delay and zero defects and were proposed by Archier and Serieyx [307]. Figure 2.19 shows that there have been three major paradigm shifts in manufacturing.

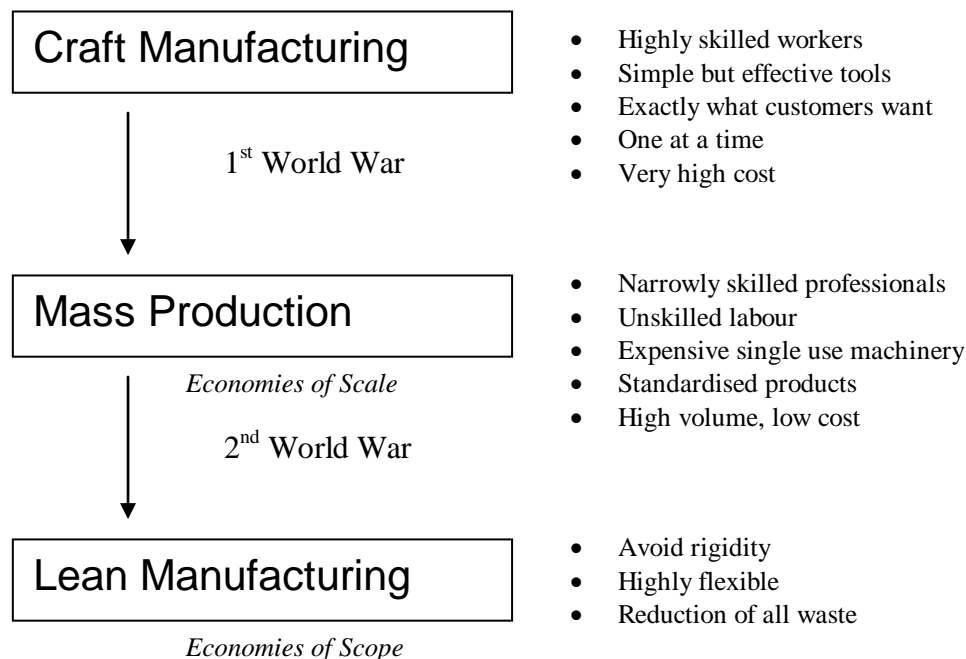


Figure 2.19: *Manufacturing Paradigm Shifts, Rigby et al [308].*

The various part-manifestation of the NWM methodologies contain elements, which overlap, and elements, which are distinctive in themselves. Storey [86], McCarthy [309] and Tharumarajah et al [310] provide additional examination, comparison and comment about various NWM classifications and concepts. Introductions to a sample of most recent NWM strategies (Agile, Lean, Virtual and Holonic) are presented in the next four sub-sections of this thesis.

2.4.1.1 Agile

Agile Manufacturing may be seen as one of the most recent manufacturing strategies to emerge from the manufacturing community. It is said by Shewchuk [311] to be 'a new paradigm for coping with the dynamic and turbulent manufacturing environments of the twenty-first century'. The term Agile Manufacturing was devised in 1991, when an industrial group observed that the rapidly changing business environment was rapidly outpacing the adaptability of traditional manufacturing enterprises. A contingent of academic researchers, industrialists and government agencies co-operated in a project at the Iacocca Institute of Lehigh University. The '21st Century Manufacturing Strategy Project' was concerned with re-invigorating the US world dominance in manufacturing. This work was highly conceptual and could be open to misinterpretation [310]. Within the concept of agile manufacture, enterprises seek to combine the advantages of time-based competition [312] with techniques to reduce the cost of variety while remaining adaptable to future changes. Booth [313] proposes, 'the intention is to be able to offer almost instant delivery of small quantities of goods with individual specification. The four principles of agility aim to support this:

1. Enriching customers - Products Vs Solutions [314].
2. Co-operating to enhance competitiveness - Virtual Corporation [314].
3. Mastering change and uncertainty - Entrepreneurial Organisations [314].
4. Leveraging - Impact of People and Information [314].

To successfully achieve in agility is very difficult in practice and maybe an impossible goal for most enterprises [314]. As competitive pressures increase and the plateau of the value portfolio is raised by competitors globally, many enterprises will need to focus upon exploiting key competencies in which they can excel. Problems coping

simultaneously with complexity and change will limit the ability of an enterprise to broaden its provision of products and services to ever more discerning set of customers [310]. Such constraints are key drivers to the formulation of partnerships and joint ventures between businesses [315].

Sharifi et al [316] studied agility with respect to the UK Manufacturing industry and proposed a methodology for moving towards agility. They comment that much additional effort is needed to keep pace with the current rate of business change. Yusuf and Sarhadi [317] have developed a framework for evaluating enterprise agility based upon 5 principles. This has been implemented as a computer model and provides a valuable methodology of assessing an enterprise's attributes of agility. A general overview of the agility concept is provided by Kidd [318].

2.4.1.2 Lean

Lean manufacturing has been viewed as being a complex manufacturing strategy, which concerns the entire enterprise from product development right through to invoicing customers [35]. It has been said to incorporate two major aims [319] namely, 1) the pursuit of excellence, in terms of performance and continuous improvement and 2) the re-thinking of work organisation, in order to gain a flexible and effective organisational structure. An early inspiration for the 'lean' concept was Henry Ford's moving production line principle. He commented in the 1926 *Today and Tomorrow* article that, 'Having a stock of raw materials or finished goods in excess of requirements is waste. Like every other waste it turns up in high prices and lower wages'. Much later Taiichi Ohno pioneered a development of the lean concept with the Toyota Production System [320] [321]. He freely admitted [322] his admiration for Henry Ford and recognised that he had adopted and followed principles developed much earlier by the Ford motor company.

The realisation of lean principles and their adoption by manufacturing enterprises was popularised further, following a 5 year study undertaken by Womack et al [35] with reference to the future of the automobile. These authors explained how enterprises can dramatically improve their performance by embracing the 'lean production' approach pioneered by Toyota. Womack and Jones continued [323], that 'by eliminating unnecessary steps, aligning all steps in an activity in an continuous flow,

recombining labour into cross-functional teams dedicated to that activity, and continually striving for improvement, companies can develop, produce and distribute products with half or less of the human effort, space, tools, time and overall expense'.

In its simplest form lean production has been said to be the elimination of waste, duplication and unnecessary cost [324]. Ahlstrom and Karlsson build upon this notion further and suggest that lean manufacturing should be based upon seven basic principles [325].

1. Elimination of Waste [326].
2. Continuous Improvement [326].
3. Zeros Defects / JIT [326].
4. Pull Instead of Push [326].
5. Multi-functional Teams [326].
6. Decentralised Responsibilities / Integrated Functions [326].
7. Horizontal and Vertical Information Systems [326].

Researchers within the Lean Enterprise Research Centre of Cardiff Business School have considered the application of lean techniques to complete supply chains [272] and have developed a set of 'Value Stream Mapping Tools'. The principle of these tools is to facilitate a systematic approach to waste removal [327]. Little consideration, though, has been paid to lean action programmes where enterprises have matured and reached an equilibrium point where supply equals demand [328]. From this point onwards, under conditions where competition has intensified because of over capacity and lack of real market growth, enterprises must move forward and be creative enough to increase the demand for their offerings. Creating and sustaining the attractiveness of the products and services of an enterprise is not really covered within any of the lean definitions and principles covered above.

2.4.1.3 Virtual

Notions about virtual enterprises have regularly been considered to be a way forward in realising strategies of agile and lean manufacture [315] [329]. The term 'virtual enterprise', like most other buzzwords, has been used in a variety of business contexts and has been claimed to promise success [330]. The National Industrial Information

Infrastructure Protocols (NIIP) consortium has defined a virtual enterprise as 'a temporary organisation of companies that come together to share costs and skills to address business opportunities that they could not undertake individually' [331]. Market globalisation and the rapid advances in IT, such as the Internet, are driving the emergence of the virtual enterprise [332]. By considering where enterprises add value Rayport and Sviokla [333] argue that the physical value chain is only one side of the equation. They claim that in every enterprise where there is a physical value chain, there also exists a 'virtual' value chain. Where the traditional value chain is effectively a series of interrelated functions within any enterprise that link its inputs to its outputs [286], the virtual chain refers to the value that can be generated by exploiting information generated by any stage of this process. In this way, information continued within a physical value chain is merely one part of the supporting infrastructure and that its reuse within a virtual value chain leads to commercial value. Figure 2.20 shows how the physical value chain can map to the virtual one. Physical value chain business processes and information are now supported by distributed companies and systems that enable collaboration to create new products, services and facilitate entry to new markets [334].

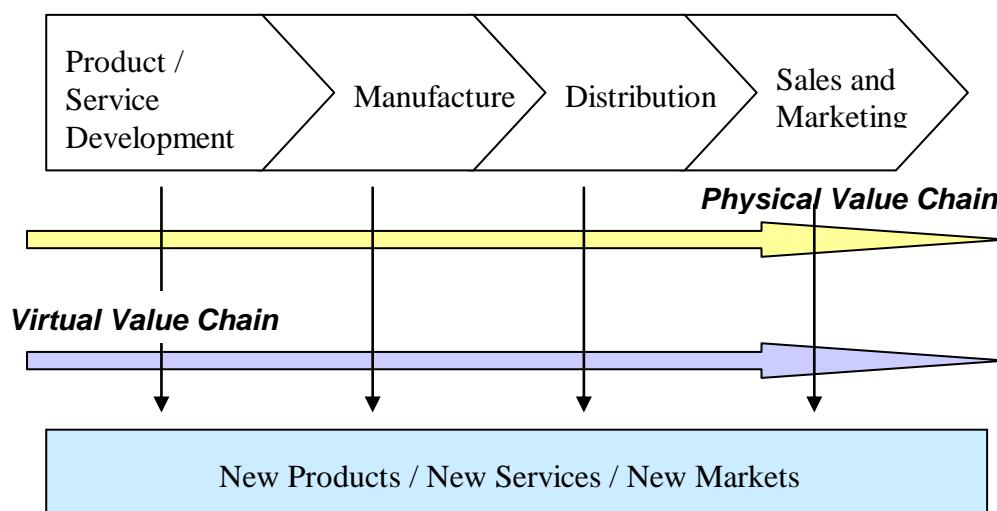


Figure 2.20: *The Virtual Value Chain, Czerniawska and Potter [334].*

It is often assumed that virtual enterprises are designed and constructed as a temporary group of distributed businesses [332]. Pape [335] suggests that any non-virtual enterprise may make the switch to a virtual one and proposes an eight-step approach,

utilising motivation and information sharing as key concepts for driving the transfer. Principal business reasons that can drive such a transfer include:

- Reduced Building and Overhead Expenses [336].
- Increased Productivity [337].
- Higher Profits [338].
- Improved Customer Service [338].

Obviously, these perceived benefits have to be offset against increased infrastructure and communications costs. Venkatraman and Henderson [339] proffer that, 'the current models of strategy and structure are woefully inadequate to meet the imminent challenges of the information age'. They reject the virtual enterprise as a distinct structure, but instead treat 'virtualness' as a strategic characteristic that is applicable to every enterprise. Clements et al [340] concentrate upon the use of IBM's Aglets Workbench and mobile agents to enable the virtual enterprise. The authors utilise a component-based approach to system development based on an underlying architecture that positively supports the requirements and characteristics of an agile enterprise. This research also believes that 'current generation software systems will not actively enable the agile enterprise'.

2.4.1.4 Holonic

A unifying theme running through the 'Holonc Manufacturing Systems' (HMS) concept is the notion of a holon. This term was coined by Koestler [341] and is considered to mean simultaneously a whole and a part of the whole. The word holon is constructed from a combination of *holos* (a Greek word for whole) with the suffix *on* which, as in proton or neutron, suggests a particle or part. The derivation of the holon was related to two observations made by Koestler. The first was from Herbert Simon and was based upon his parable of two watchmakers where he concluded that 'complex systems will evolve from simple systems much more rapidly if there are stable intermediate forms than if there are not'. The resulting complex systems will be hierarchic. The second observation came from analysing hierarchies and stable intermediate forms in living organisms and social organisations. Although it is easy to identify parts or sub-wholes, parts and wholes in an absolute part do not exist

anywhere [310]. Further to this, it is suggested that the holon is an entity which has two distinctive aspects; i.e. autonomy and a willingness to interact with other holons [282]. Figure 2.21 details holons, a holarchy and co-operative concepts.

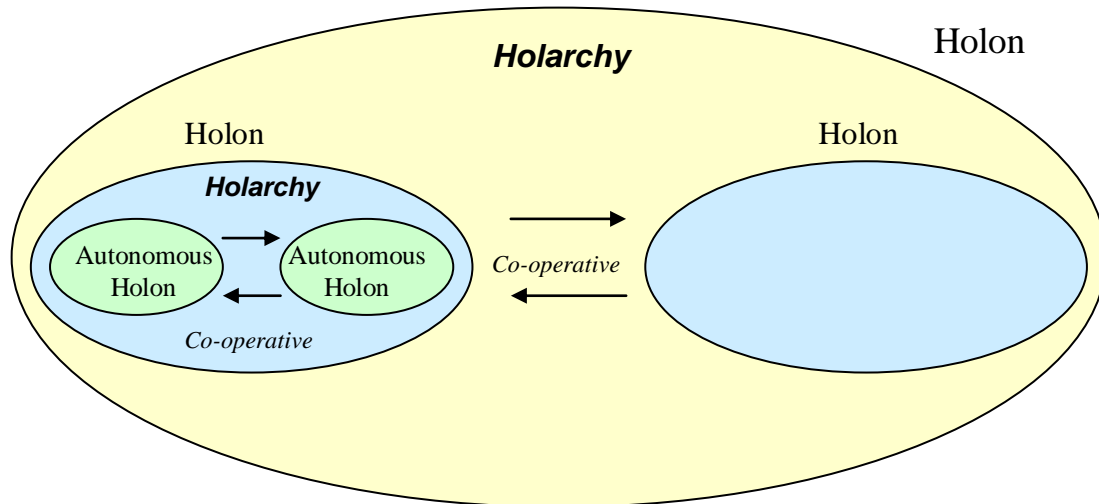


Figure 2.21: *Holarchy and Co-operative Concepts, Tharumarajah et al [342].*

Suda [343] [344] initially took the holon concept and translated it into manufacturing terms. This was then developed by the Intelligent Manufacturing Systems (IMS) programme to provide the foundations of a valuable view of prospective lower compositions of the manufacturing industry [345]. The following list of definitions has been proposed by the HMS consortium to provide guidance upon the holonic concept.

1. **Holon:** An autonomous and co-operative building block of a manufacturing system for transforming, transporting, storing and/or validating information and physical objects. The holon consists of an information processing part and often a physical processing part. A holon can be part of another holon [346].
2. **Autonomy:** The capability of an entity to create and control the execution of its own plans and/or strategies [346].
3. **Co-operation:** A process whereby a set of entities develops mutually acceptable plans and executes these plans [346].

4. **Holarchy:** A system of holons that can co-operate to achieve a goal or objective. The holarchy defines the basic rules for co-operation of the holons and thereby limits their autonomy [346].
5. **Holonic Manufacturing System (HMS):** A holarchy that integrates the entire range of manufacturing activities from order booking through design, production, and marketing to realise the agile manufacturing enterprise [346].
6. **Holonic Attributes:** The attributes of an entity that make it a holon. The minimum set is autonomy and co-operativeness [346].
7. **Holonomy:** The extent to which an entity exhibits holonic attributes [346].

The concept of holonic manufacturing has now been applied to a variety of practical and industrial situations. Moriwaki and Sugimura [347] have considered operational aspects of scheduling holons in an environment of manufacturing cells and robots having distributed control. Bell and Newman [348] have provided a holonic conceptualisation of an IT supported SME, consisting of three sub-holons: the executive holon that represents the decision-making process within the enterprise, the business holon that covers administration activities and the manufacturing holon to implement production plans. Nakane and Hall [349] class HMS as a 'bright vision'. The authors' intention is to create simple high-tech systems that do not strangle in their own complexity. They suggest major changes need to be made to enterprise: human resource management, improvement processes, supplier networks and product design systems to fulfil the promise of holonic manufacturing.

2.4.2 Computer Integrated Manufacturing (CIM)

Computer Integrated Manufacture (CIM) is a multidisciplinary subject and it is important to understand it as a wider perspective to integrated Computer Aided Design (CAD) and Computer Aided Manufacture (CAM). One definition of CIM suggests that it is a complex multi-layered system designed for the purpose of minimising waste and creating wealth in the broadest sense [21]. The concept of CIM was initially coined by Joseph Harrington [350] but CIM did not really become a common manufacturing philosophy until the 1980s. According to another definition CIM is aimed at integrating man and machine activities by facilitating communication, co-operation and co-ordination of the various technical, administrative and support functions of a

manufacturing enterprise [3]. The methodologies and technology applied in CIM make widespread use of distributed computer networks, data processing techniques, Artificial Intelligence (AI) and Database Management Systems (DBMS) [232]. CIM, therefore, can be perceived as a broad blanket term used to cover all the activities related to a manufacturing environment and may be targeted at linking islands of computerisation or automation [162]. These activities include things such as:

- Evaluating and developing different product strategies [21].
- Analysing market trends and creating forecasts [21].
- Systems integration to facilitate integrated information flow between upstream and downstream functional activities (i.e. engineering, production and management), and integrated material flow to support part production [162].
- Enhancement and optimisation of manufacturing processes [162].
- Analysing process feedback, economic parameter and data to provide reports at the appropriate level, format and the correct time [21].

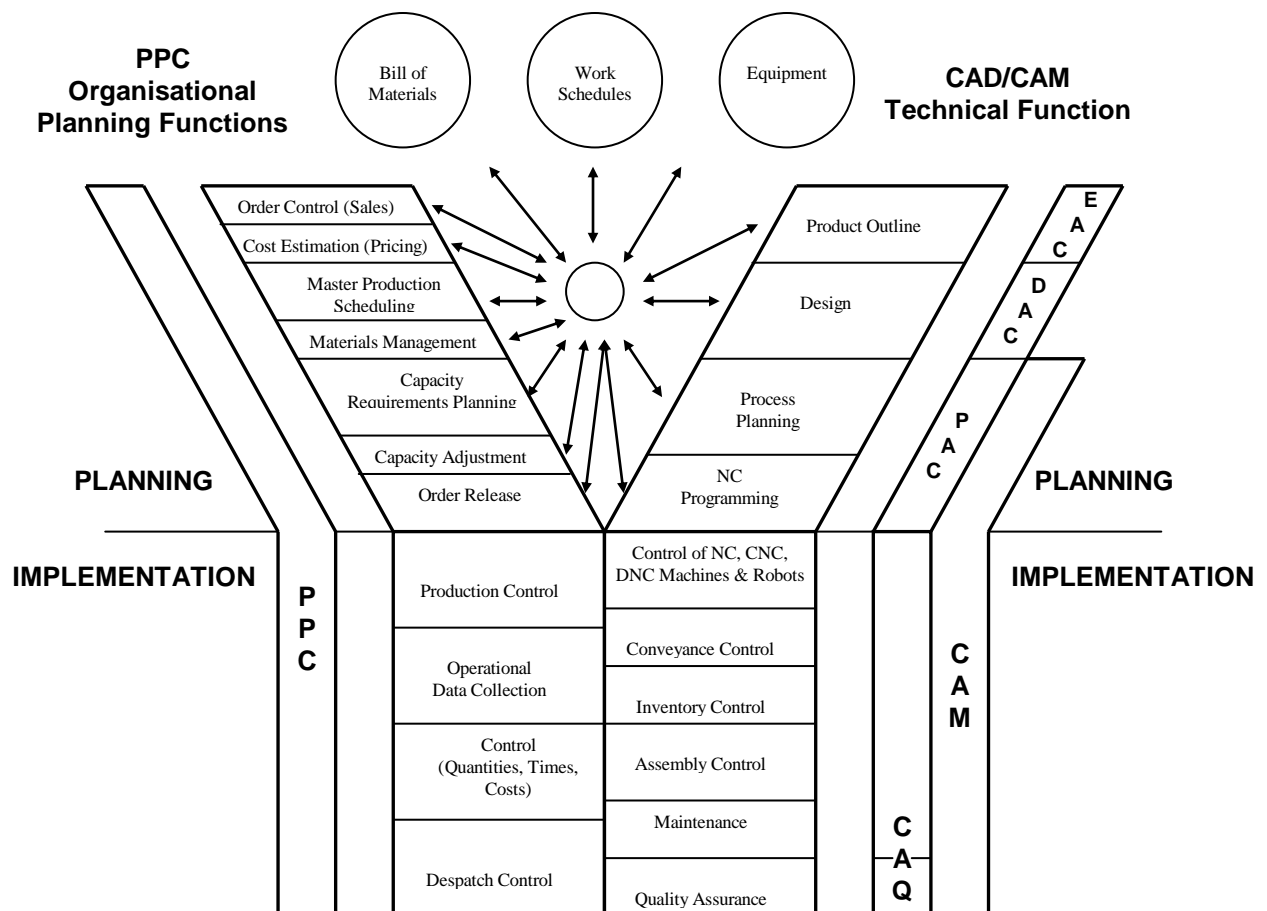


Figure 2.22: *Information Systems in Production, Scheer [232].*

It can now be seen that CIM has the aim of allowing advanced information processing, database management and expert system technology to penetrate into all the components of manufacturing systems and its management. 'CIM is an innovative and expansive concept to provide the solutions, manufacturing industries are seeking to survive in the competitive global market' [351]. A general model of some important CIM subsystems and their functional relationships can be seen in Figure 2.22.

In 1984, NASA asked the National Research Council (NRC) to study the impact of integration efforts at McDonnell Aircraft Co., Deere and Co., Westinghouse Defence and Electronics Centre, General Motors and Ingersoll Milling Machine Co. The NRC's committee on the CAD/CAM interface checked the results carefully before printing them. The committee found that these companies had already received significant benefits, even though they were only partially into their 10 to 20 year integration efforts [27]. Table 2.6 summarises these benefits.

15-30%	Reduction in engineering design cost.
30-60%	Reduction in overall lead time.
40-70%	Increased productivity of production operations.
30-60%	Reduction of work in progress.
2-5 times	Increased product quality as measured by yield of acceptable product.
3-35 times	Increased capability of engineers as measured by extent and depth of analysis in same or less time.
2-3 times	Increased productivity of capital equipment.

Table 2.6: *Integration Benefits, Rembold et al [27].*

CIM has recently been connected with the concept of virtual manufacturing [352] and is said by Nagalinam and Lin [351] to 'provide all the features of lean, agile and concurrent manufacturing in an integrated manner'. Ari Samadi and Hoang have proposed the utilisation of 'Shared CIM' to combat the high initial investment costs associated with the deployment of CIM [353], whilst Marri et al [354] have investigated the application of CIM technology to SMEs. McGaughey and Roach [355] consider the planning aspects of CIM systems and Sackett and Heslop [356] have considered modelling strategies for the appraisal of CIM systems.

2.4.3 Concurrent Engineering

Concurrent Engineering (CE), or simultaneous engineering as it is often referred to, is a conceptual way of working where the various engineering activities in the product and production development are organised and performed in an integrated manner and where possible in parallel rather than in sequence [357]. CE systems are generally expected to comprise multi-disciplined teams each with specific but dependant roles and responsibilities. CE tools take the form of algorithms, techniques and software and the expertise and judgement of people who make up the complete design and production sequence. The scope of CE has been viewed as encompassing the integration of product design and process planning into a unified activity [358]. CE is an integrating strategy that potentially can be applied beneficially in many environments using the integration aspects of CAD/CAM methodologies. CE philosophy is defined by Winner et al [358] as:

'A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture support. This approach is intended to cause the developers, from the onset, to consider all elements of the product life-cycle from concept through disposal, including quality, cost, schedule, and user requirements'

Key issues in CE are related to carefully arranged teamwork, simultaneously targeted design and engineering tasks and the early exploitation of manufacturing knowledge in the design phase [3]. Molina et al [359] believe that the constant availability of relevant, reliable and consistent product and manufacturing information is a key to the effective utilisation of computer systems which support CE. In a survey by Stevenson [360] current IT tools that are required for CE are identified and categorised into four groups:

- 1. Product Information Management (PIM):** PIM tools are configuration management information systems, which organise data produced on computers to serve engineering, analysis, manufacturing and management [360].
- 2. CAD Frameworks:** These are specific application frameworks to improve performance during the design process and are based upon a set of standards for CAD data exchange, such as IGES and STEP [360].

3. **CSCW (Computer Supported Collaborative Work):** A CSCW tool is an information system which supports team work by providing enabling technologies such as computer networking and its associated hardware, software, services and techniques [360].
4. **Electronic Design Engineers Notebooks:** These are hypermedia systems that readily permit the extraction of information from past engineering records [360].

CE can employ integrated CAD/CAM as its basic backbone with further tools for integration, such as reasoning systems and neural networks. Successful CE systems are likely to make extensive use of teamwork and by doing so can tear down long-standing walls between separate departments [361]. Typical elements of CE systems are illustrated in Figure 2.23.

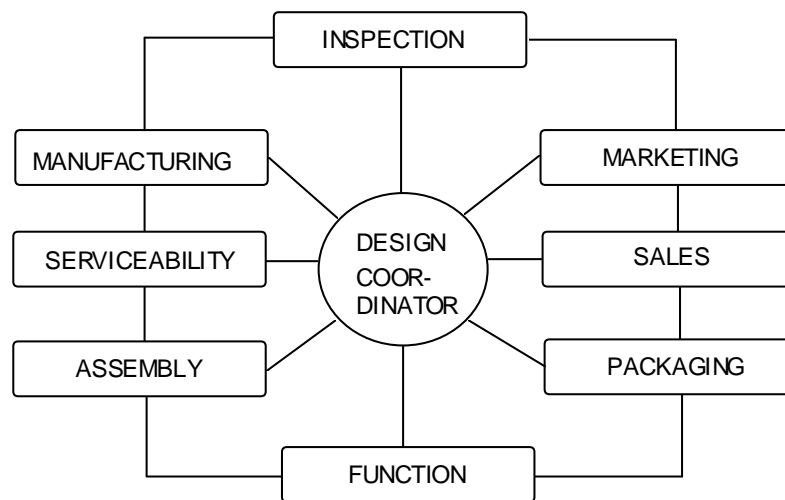


Figure 2.23: *Concept of Concurrent Engineering, Bedworth et al [362].*

CE principles have been successfully applied to industrial situations such as the design of a light helicopter [363] and the production of the Volkswagen Golf and Jetta cars, [364]. By applying CE principles to the Golf production line, an engine installation bottleneck was reduced from one minute to 26 seconds, therefore the assembly line cycle time could be nearly halved and a cost saving could be realised using robots and slightly more expensive screws. The MOSES (Model Orientated Simultaneous Engineering System) Project [359] [365] developed a reference model to assist in the provision of computer support for CE. Shetty and Kolluri [366] considered CE applications in the aerospace industry and Schneider et al [367] examined the

integration and co-ordination of major software systems with workflow management systems to implement CE.

2.4.4 Modes of Manufacturing Control

Effective and efficient manufacturing production depends upon the accurate control of material, processes, people and information at a number of levels throughout the value chain. This may be viewed as a demanding and complex range of interacting tasks upon which enterprise management has been working towards for many years. Scheduling concepts can be utilised to assist with this endeavour. [368]. In general there are four classes of manufacturing attributes that need to be considered when making scheduling decisions: cost, time, quality and flexibility, Figure 2.24. These manifest themselves, depending upon the particular problem, into specific objectives, goals and criteria [369].

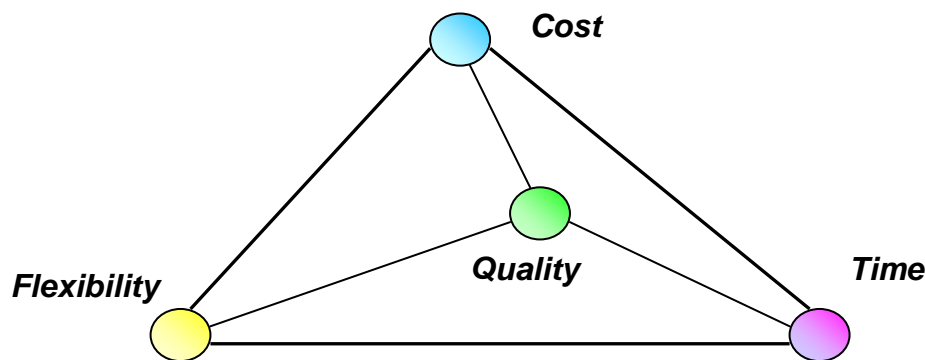


Figure 2.24: *The Manufacturing Tetrahedron, Chryssolouris [368].*

The term 'scheduling' can be applied to manufacturing to describe the variety of business processes involved in manufacturing production, such as job shop control, resource organisation and entire supply chain management [370]. Much research has been conducted to investigate scheduling [370] [371] [372] [373] [374]. Mackay and Viers [375] have proposed a framework to unify the theory and practice of production scheduling and generally describe scheduling as 'allocating a set of resources over time to perform a set of tasks'. Ortiz [376] has analysed scheduling implementation issues and proposed a 8 step approach for scheduling success. Burrows and Polkinghome [377] have considered new scheduling concepts such as Artificial Intelligence and Genetic Algorithms, together with their application to SMEs.

Bertrand et al [378] consider the decomposition of production systems into hierarchically organised planning and control structures to reduce the complexity of the scheduling problem. They further distinguish between 'goodsflow' control, which concerns planning and control decisions on the factory level and production unit control, which concerns planning and control decisions at the production level. The notion of a decoupling point is used to separate production units and provide an entry point for the goodsflow control.

The position of a Customer Order Decoupling Point (CODP) is an important characteristic of a manufacturing enterprise. The CODP represents how far a customer order penetrates the manufacturing cycle. Based upon its position, an enterprise's manufacturing environment can be classified into one of the following categories: Make-To-Stock (MTS), Assemble-To-Order (ATO), MTO or ETO. The CODP usually coincides with the last main stock point in the product flow [379], Figure 2.25.

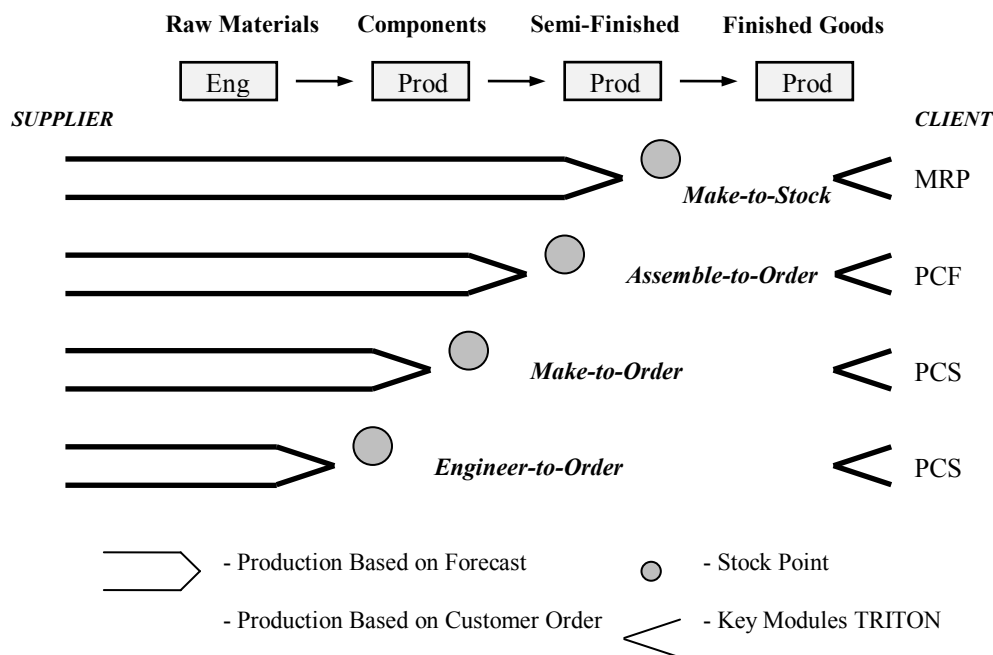


Figure 2.25: *Customer Order Decoupling Point, Baan [379].*

When considering scheduling further, the type of inventory involved and the production management mechanism for controlling its creation are key factors [22]. Inventory can be classified into two groups:

- a) Independent demand inventory: which are the final demand goods - the goods that will be consumed or used up by the customer as finished goods [380].
- b) Dependant demand inventory: which consist of items that are used in the manufacture of the finished products [380].

Primary production management philosophies are detailed below, but there exists a key point that should be considered. Namely that there may seem to be large differences between the concepts embodied into a production management philosophy and their implementation as production management mechanisms that industry can deploy readily, e.g. MRP production concepts may be much richer than commercially available MRP type systems [10].

Material Requirements Planning (MRP): MRP is a demand dependant system, based upon a master deliveries schedule for a forthcoming production period. This represents the required production output for the periods in terms of product types, quantities and due dates [380]. A parts list or Bill of Materials (BOM) is associated with each product type and the current inventory records. Lead-times are then combined with minimum inventory levels to determine time-phased requirements for each item of inventory in order to generate the information needed for appropriate inventory ordering action, such as raising purchase or works orders [381]. MRP is vulnerable to rogue demand forecasts and material supply problems. However it can yield much lower inventory costs than demand independent systems [22]. It also offers better customer service from better control of stock shortages and less costly fire fighting [380].

Manufacturing Resource Planning (MRPII): MRPII is an extension of MRP and the basic notion is that a master deliveries schedule for a period actually defines all the resources needed to generate the planned output, not just its material requirements [381]. It is made up of a variety of inter-linked functions that include, business planning, production planning, capacity requirements planning and an execution system for capacity planning and priority scheduling [355]. MRPII systems can be integrated with financial reports to provide cost and variance reporting [382]. The main problem with MRPII systems is that they are top down, requiring accurate planning at the

master production scheduling and planning levels. MRPII systems if implemented effectively can deliver very worthwhile rewards [22]. The relationship between MRPII and finite scheduling are investigated by Little et al [383]. Enterprise Resource Planning (ERP) systems have come to the fore in recent years and are seen to offer a fundamental advance of MRPII concepts. ERP systems build upon MRPII and are characterised by increased scope and functionality for items such as, multi-company, multi-language, multi-currency, distribution and shop floor support [8] [9]. ERP both as a concept or a production mechanism is discussed further in section 2.5.5.

Theory of Constraints (TOC): TOC can be viewed as a management philosophy that has been used in many industrial domains. In the manufacturing environment, the goal is making money in both the present and the future. The goal is accomplished by 1) maximising throughput (rate of sales); 2) by minimising inventory (material cost of goods not yet sold) and 3) by minimising expenses, all money spent to turn inventory into throughput. This includes direct labour, overhead and all capital goods [382].

The first reported use of TOC was in an American shop floor planning and control program called OPT (Optimised Production Technology) and was marketed by Creative Output at the beginning of 1979 [384]. The program was developed by, Eli Goldratt who then went on to expand its principles into TOC [385] [386] [387].

A key principle of TOC is that only a few, work centres within the factory control the output of the entire enterprise for each product line. Managing these, capacity constrained resources or bottlenecks optimises the output of the factory. Knowledge and understanding of the plant's bottlenecks will provide guidance for future plant investment [381]. Hutchin [388] argues that implementations of TOC concepts can be perceived to be failures, as they are often obliged to conform to out-dated cost based performance measures.

Just-In-Time (JIT): JIT is a manufacturing paradigm which attempts to reduce procurement delays and procurement stocks as much as possible. It presumes a very good integration for information exchange between stakeholders in the enterprise and relies upon effective logistic systems [3]. In JIT the maintenance of inventory is an unnecessary evil. Inventory only exists to cover short-term mismatches between input

supply and output demand and impose an economic burden on the enterprise in doing so. This is avoided if mismatches can be eliminated [22]. So JIT aims to arrange that the right materials arrive where they are needed just as they are needed. In this sense, JIT is a logical extension to MRP. JIT can eliminate inventory, whereas MRP only reduces it to a minimum safety level [389].

The original and most complete realisation of JIT was the Toyota Production System. It utilised pull scheduling to control daily production activity [390]. This is in contrast to MRP and OPT push scheduling where all activities follow a predetermined plan [391]. The pull system can be supported by the use of kanbans to activate production activities. These are three variations on the kanban theme: cards, square and containers. Essentially, the idea is to use the depletion of inventory at one stage in the manufacturing process to trigger an upstream process to manufacture a replacement batch [381]. The implementation of JIT in an SME is reviewed by Sohal and Naylor [391].

Samson [391], Vollman et al [393] and Plenert [394] have provided additional general literature upon production control concepts. Lee and Park [395], emphasise the problem of undertaking scheduling in MTO environments when process plans are not yet available. Little et al [396] have undertaken key investigations, closely aligned to the research presented in this thesis, upon integrated planning and scheduling in the ETO sector. They comment upon the significance of SMEs in the business community and mismatches that may occur between generic propriety software and business need. Several issues related to the ETO sector are identified and the development of GRAI reference model considered. Whilst this work can assist enterprise management to better understand their order-fulfilment processes it does not address the fundamental limitations of current manufacturing IT systems.

2.4.5 Mass Customisation

Mass customisation can be classed as a trend towards the production and distribution of individually customised goods and services for a mass-market [397]. Potentially this can be achieved through the use of technologies that increase speed, capacity, flexibility and efficiency of product realising processes. Use of these technologies, combined with a suitable organisational transformation, can be used to deliver

individually tailored versions of products and services at affordable cost. This though is currently very difficult, if not impossible, to achieve in practice on any significant scale or over a sufficiently long time frame [19]. Competitive advantage in mass customisation may be derived from creating the most value at the least cost on a highly market-segmented basis.

Mass customisation was first portrayed by Pine [398] in a survey of US enterprises. He then went on to develop the concept in the Harvard Business Review [399]. Alternatively, as this initial view supports the assumption that mass customisation is an inevitable successor to mass production. Kotha [400] provides a different standpoint based upon his work at Panasonic. He suggests that mass customisation and mass production could exist in the same enterprise and would deliver benefits from the synergy between them. This belief is further supported by Hanson [401], whose work on the 1996 IBM Study Mission visit to Japan, also included a visit to Panasonic.

Enterprises that use mass customisation attempt to profitably deliver a specialised product or service to a focussed market segment by:

- Reducing the time to market across the Value Chain [402].
- Transforming enterprise structures to increase flexibility and responsiveness while reducing costs [402].
- Designing products or services that are modular [402].
- Producing components that can be assembled into a large number of end products and services [402].
- Introducing a flexible manufacturing system that produces families of products, reduces set-up and change-over times, and reduces costs [402].

A key to mass customisation is the degree of perceived differentiation to the customer. In the 1970s and 80s large enterprises such as Coca-Cola, Bennetton and Nike saw the development of brand identity as a means of differentiating products and creating customer loyalty. More recently, as customers have started to make more informed purchases, enterprises such as IKEA and Boots have introduced smart cards and services to acquire information about their customers and differentiate themselves by making transactions simpler [334].

Technology such as the Internet is now empowering consumers with information and changing the balance of power from the corporate manufacturer to the individual purchaser. What this means is, as more and more people have a wider choice through channels such as the Internet, brand identity will shift from readily identifiable products to service and how enterprises can deliver to an individual, the items that an individual wants and when. This has the wider impact, back through the supply chain to factory shop floor and assembly points [403]. Fox [404] makes the distinction, that mass customisation is fundamentally different to product personalisation. This is because product personalisation relies upon some design authority being relinquished to the customers.

From survey work, Alhstrom and Westbrook [405] class, Understanding What the Customer Wants?, Supply Chain Management and IT, as the top three respective problems related to the successful implementation of a mass customisation approach. They further comment, that mass customisation was historically seen as a problem of 'variety and flexibility', but enterprises now not only perceive mass customisation as something which is currently happening, but also as something which will be even more important in the future.

2.4.6 Critique - Manufacturing Techniques

The application of different manufacturing techniques to enterprises can be considered to be akin to the management concept trends previously reviewed within this chapter. Throughout recent time, re-branded manifestations of old strategies have re-emerged, together with completely new ones (e.g. virtual), which address specific business issues (i.e. to support low cost globalisation). The overall goal of these techniques can be viewed as achieving control over complexity. As business has moved away from manual and paper-based control of local, craft-based, production operations into global, information intensive and highly automated production a rise has been seen in the deployment of IT. MRP/MRP II and ERP systems are now routinely used to assist enterprises to control manufacturing complexity and CIM based systems are now utilised in many plants to increase production efficiency.

Currently, two major factors appear to be driving manufacturing within the UK, 1) a requirement to substantially reduce direct production costs to remain

competitive and 2) a customer requirement to routinely offer increasingly customised products and services at affordable costs. Transferring production to countries that provide a lower cost base may combat (1) but (2) is something that in practice is considered to be very difficult if not impossible.

The provision of strategies, systems and techniques to satisfy the two points above is key. (1) May be viewed as a further increase in complexity that can be supported by the further deployment of IT, whereas (2) can be attributed to the underlying MRP foundation on which current production systems are generally based. Regardless of what consultants and vendors may proffer, the deployment of such MRP driven systems cannot adequately provide support for customisation or ETO/MTO manufacturing as there is no way to determine demand until order acceptance and product design has been completed. A fundamental re-thinking of manufacturing support for ETO/MTO and personalised manufacture is required as a matter of urgency as little research is currently being devoted to this emerging issue.

2.5 Information Technology Perspective

This section of the literature survey considers the management, development and implementation of IT within manufacturing enterprises. IT strategy and recent advances in manufacturing business systems are explored, together with an overview of complementary IT systems.

The challenge of managing enterprise IT has been a subject of great interest within the IT community for many years, and it has recently become an issue of concern for senior enterprise management as well [406]. Benton states [407] 'The issues posed by the strategic use of IT are now urgent as the global economy is rapidly changing'. New businesses are creating threats in each industry, barriers to market entry are falling, enterprises are moving increasing freely from industry to industry and the world markets are becoming global. Amazon.com has currently become the world's leading Internet bookseller and supermarket chains regularly sell financial services such as insurance and pensions [408]. The Internet revolution or more specifically electronic commerce, will place unprecedented stress on the contribution of IT to the enterprise, but can be seen as a valuable opportunity for enterprises to create further value for its customers, employees and business partners [409].

Colin [410] proposes that, 'The role of IT in an enterprise has evolved from its predominant focus on automation to achieve greater efficiency to a wider role as a fundamental business enabler'. IT can provide the means not only for improved customer products and services, or lower cost, but also, for example, for creating and maintaining a flexible business network of inter-enterprise arrangements. IT can be instrumental in facilitating joint ventures, alliances and partnerships, technology licensing, marketing and contract agreements. Overall, the thoughtful use of IT can add value, reduce costs or gain competitive advantage in any area of an enterprise's business [411]. Research by Browning et al [412], suggests that the following key business and IT trends will considerably affect SMEs, in and beyond the year 2000.

- IT spending, internal and with external service providers, will move from infrastructure maintenance to customer care and business enablement [412].
- E-business requirements will result in significantly increased network traffic and thus dramatically increase network expenditures [412].
- Rent-able software may replace or supplement traditional software acquisition, dramatically changing customer/supplier relationships and a degree of user customisation will occur [412].
- The IT organisation within an enterprise may evolve into a broker of IT services. However, access to IT skills will become a serious management concern [412].
- As enterprises adapt to changing market places by integrating their business processes and reaching out to their supply chain partners over the Internet, the need for consistent enterprise architectural standards will become inevitable [412].
- SMEs will be increasingly prone to or affected by, mergers, acquisitions and divestitures [412].

Technological change is one of the fundamental drivers of industrial competition as it permeates at every point of the value chain [413]. It can change the rules of the field in which enterprises strive for advantage. Many of today's successful enterprises have survived due to their ability to fully exploit the technological changes present in the market place. Porter [59], comments 'It should be also understood that technological change for its own sake might not be the correct path to venture down' whereas Schroder [414] states that 'the survival of an SME is linked to the adoption of technology as a regular part of doing business'.

Lefebvre and Lefebvre [415] have studied the adoption of information and telecommunication technologies on SMEs. The utilisation of manufacturing information systems and CIM technologies increase with enterprise size, Table 2.7. Also, the positive adoption of MRP is more readily made with enterprises that typically employ MTS production strategies with products that have low technological complexity.

TECHNOLOGY	No. of Employees (% Use)			
	0-19	20-99	100-499	>=500
Design and Engineering				
CAD-CAE (Computer Aided Engineering)	28.0	35.8	55.8	81.2
CAD-CAM	8.7	10.9	13.2	27.6
CAD assisted procurement	5.1	6.0	12.2	22.4
Fabrication and Assembly				
FMC-FMS (Flexible Manufacturing Cells - Systems)	7.4	6.9	11.9	28.1
NC-CNC Machines	14.1	13.1	21.4	35.8
Materials working lasers	1.2	2.7	3.7	16.1
Pick and place robots	2.2	2.4	12.7	32.3
Other Robots	2.3	2.6	10.6	27.9
Automated Handling Systems				
AS-RS (Automated Storage and Retrieval Systems)	7.5	1.3	11.1	12.8
AGVS (Automated Guided Vehicle Systems)	4.6	0.6	3.0	8.5
Inspection and Communications				
Automated inspection equipment for inputs	15.6	8.1	15.1	45.3
Automated inspection equipment for final products	16.5	11.9	29.4	59.2
LAN for technical data (Local Area Network)	22.4	16.0	39.2	71.1
LAN for factory use (Local Area Network)	22.8	11.8	34.4	57.4
Inter-company computer network	11.6	70.7	23.8	54.6
Programmable controllers	22.5	22.6	57.0	78.3
Computers used for control in factories	24.4	24.4	49.3	71.0
Manufacturing Information Systems				
MRP	22.1	23.1	39.2	73.8
MRPII	15.7	14.5	21.6	58.6
Integration and Control				
CIM	16.0	15.7	14.8	29.8
SCADA (Supervisory Control and Data Acquisition)	17.7	15.7	30.7	4.2
Artificial Intelligence - expert systems	1.0	0.6	8.4	16.7

Table 2.7: *Advanced Technology Adoption by Canadian SMEs [416].*

2.5.1 IT Strategy

Advancing into the new millennium the managers of IT in manufacturing SMEs will be faced with major challenges and opportunities caused by heightened competition of a

global economy. Laracuenta et al [416] propose that in some industries IT may be a determinant of survival and prosperity. Whereas in others IT may be a competitive resource to facilitate differentiation and provide competitive advantage. They further suggest that 'IT decisions will be driven by factors of supply and demand'.

To achieve superior performance through the use of IT, it will be necessary for enterprises to master a series of complex issues including the technology itself, the impact of it upon the enterprise and the field of business strategy [417]. Furthermore, not only are these issues complex, but they are also dynamic, with new developments occurring regularly, requiring continual adjustment from management

The need to develop a fit between IT and business strategies has long been emphasised by researchers [418] [419] [420] and reflects the belief of Galliers and Sutherland [421], that the use of IT within an enterprise evolves over time to serve different strategic purposes. Barkan et al [422] comment that, SMEs are increasingly spending a higher percentage of revenue on IT than larger enterprises and typically have centralised IT budgets which are strongly controlled, Figure 2.26.

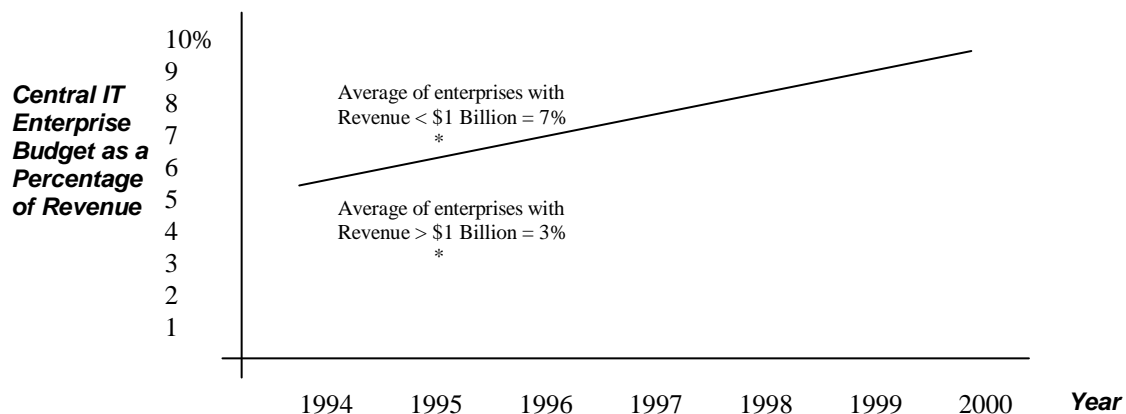


Figure 2.26: *SME IT spending as a % of Revenue* [422].

Burn [423] has focussed upon the need to consider new approaches to IT planning that more closely align IT plans with business and has suggested an alignment model. The effective measurement and evaluation of the degree of 'fit' between IT and business strategies has become an important research question [424]. Work by Scott-Morton [425] upon investigating the link between IT and business strategy suggests that IT can become interdependent with business strategies and may, therefore, require planning

approaches which support or even initiate the role of IT as a key leader of business strategy. Significant findings from the work include:

- 1) IT does not provide sustainable competitive advantage by itself. It requires integration with the enterprise's processes and structure to achieve lasting advantage [425].
- 2) IT capability is now of sufficient influence to become a driver to change the enterprise, its processes, products and even its market [425].
- 3) Although IT is an agent of transformation, significant technical problems still exist and constrain deployment of IT in the business domain [425].

Earl and Feeny [426] pose the question, 'Is your CIO (chief information officer) adding value?' and suggest an added-value framework that includes the following:

- IT involvement and continual focus on dealing with business imperatives,
- Concentration on IT service development efforts,
- A contribution directly to business beyond administrative support applications,
- Establishment and communication of a track record of unbroken IS performance,
- Establishment of an IT-business executive relationship.

The core concept of this work is the need for a vision of IT that could be shared by business and IT leaders within the enterprise. Whilst this may be very valid for larger enterprises with established IT management, it can prove more difficult for SMEs to build such relationships where IT may not have board level representation [427].

Larsen et al [428] have investigated the relationship between IT planning and business performance in the context of high-growth medium-sized enterprises and produced several findings. They conclude that in these enterprises IT planning is ingrained with all enterprises operations and that a medium term perspective is favoured. IT plans are predominately for periods of up to three years, but do not necessarily get reviewed annually. However, the use of IT planning methodologies and tools appears to be limited and generally, it is finance and accounting executives who are the spearhead for IT planning. Table 2.8 identifies the factors and associated ranking that the IT planning process covers in 57 high-growth medium-sized enterprises. The emphasis is predominately on issues concerning the management of

the IT function, but include a strategic outlook in the sense that 'opportunities' for applying IT has both high representation and the prime ranking at 2.1.

IT Planning Factors	Included	Ranking
Analyse IT trends within the industry	36	3.8
Identify opportunities for applying IT	43	2.1
Identify weaknesses in current IT applications	49	2.3
Environmental analysis (PEST)	5	3.4
Corporate assessment (SWOT - Strengths, Weaknesses, Opportunities, Threats)	15	3.1
Evaluate IT investment	37	4.0
Agree IT budgets	42	3.5
Develop IT measurement systems	18	4.9
Monitor IT projects	41	4.0
Approve IT recruitment	21	6.2
Identify IT skills training and development	36	5.0
Other	3	2.5

Table 2.8: *IT Planning Factors and Priority Rankings [427].*

Shrage [429], commenting on work by Davenport [430] and Strassmann [431], proposes that IT systems will pay off, only if their design and management are based upon the culture and politics of the enterprises they are intended to support. Beansaou and Earl [432] advocate that close attention should be paid to Japanese IT management principles when considering the correct mindset for managing IT. These include, a) judging IT investments on the basis of their ability to improve operational performance; b) selecting appropriate technology whether or not it is state-of-the-art; and c) ensuring that systems are designed to exploit the knowledge and experience of employees.

In considering how to attain alignment between generic business strategies and IT, it is possible to discern a number of different approaches to the management of the IT function. Remenyi [417] proposes that there are at least six separate generic IT strategies:

1. **Centrally Planned** - This is a top-down planning approach that attempts to combine the business strategy with the IT strategy [417].
2. **Leading Edge** - This IT strategy relies upon the enterprise to continually update its hardware and software with the latest developments available [417].

3. **Free Market** - Here, it is assumed that the individual user is the best-qualified person to determine his own needs. In such circumstances the user is entitled to purchase his own hardware, software and services, whether internal or external to the enterprise [417].
4. **Monopoly** - This generic IT strategy rests upon the premise that there should only be one single source of computer service in the enterprise. This source is deployed to meet end-user demand within a reasonable cost structure and timeframe [417].
5. **Scarce Resource** - This approach relies upon the intensive control of money being spent on IT and often budgets may be set before the true demand for IT is known [417].
6. **Necessary Evil** - This strategy is based upon the belief that the use of IT should be limited as much as possible. Only applications, which cannot be performed without the use of a computer and which are very well cost justified, are entertained [417].

A further strategy titled as 'me-too' is proposed by Hale [433]. This is perceived as a safe choice, where the objective of IT is to match competitors capabilities rather than trying a more attractive but risky approach.

A more likely way to achieve the potential benefits to be derived from IT, is to establish effective linkages between the generic business strategy of the enterprise with the selected IT strategy [423]. It would clearly not be appropriate for an enterprise pursuing a generic business strategy of differentiation [56] to select a scarce resource IT strategy.

Johnson et al [411] suggest that gap analysis should be undertaken when considering IT-based enterprise change. Firstly, there is a gap between current business capability and the capability required to ensure success in the market, and secondly, there is a mismatch between the business needs and the ability of IT to provide support, Figure 2.27.

2.5.2 The Internet and Electronic Commerce

The Internet and electronic commerce can be said to be both, over-hyped and under valued [433] [434]. Siebel and House [435] suggest that we are now on a path that will radically alter how we interact not only with computers, but with one another, with institutions both private and public, and with business associates around the globe.

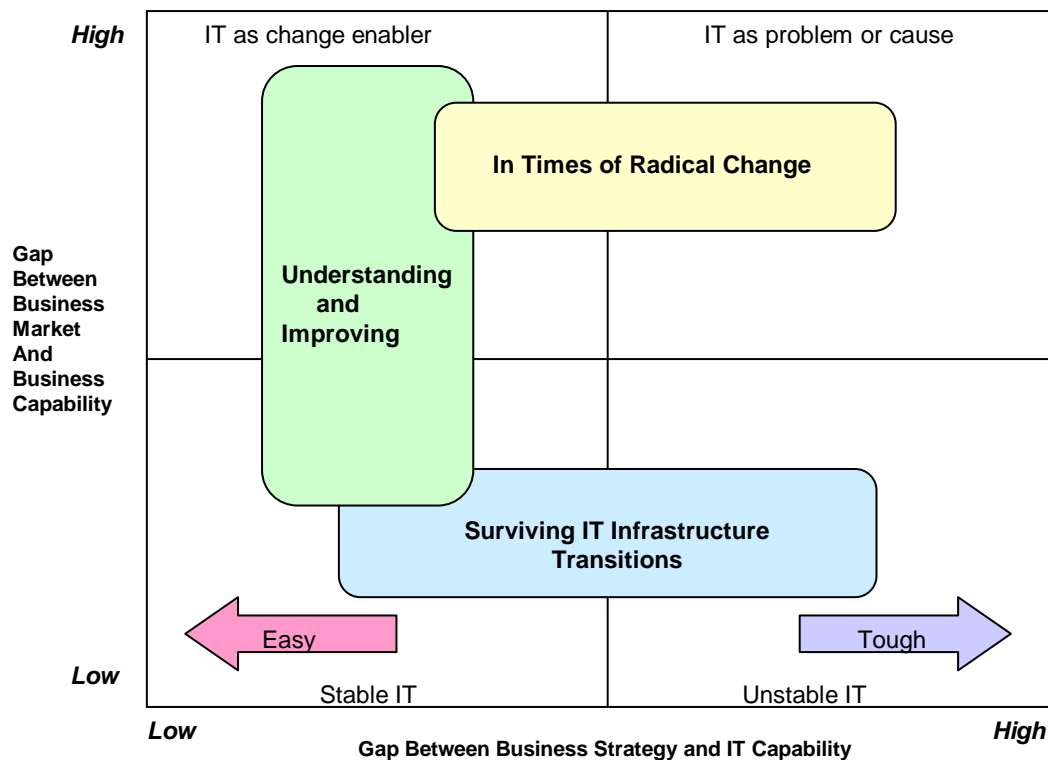


Figure 2.27: *The Required Gap Analysis* [411].

The Internet is not exactly a new invention; however, with the advent of the World Wide Web (WWW) in 1993 it has taken a new image that has stimulated interest in the business community [436]. The Internet is a global network of computers that grew out of US government and research institutes. During the 1960s, the US military faced the realisation that their communications and network infrastructure could be placed at risk, in time of war, due to its centralised nature. The solution was APRANet (Advanced Research Projects Agency Network) which was designed as a robust communications platform that could still perform as normal when parts or segments were unavailable [437]. The APRANet architecture allowed information to travel the network in a specific format, Internet Protocol (IP), each containing information about its origin, destination and the data contained. In the late 1980s, the National Science Foundation (NSF) of America decided to connect five massive supercomputer centres to provide access all over the country, but soon the project faced bureaucracy and great pressure. As a result, the founders of the project created their own network entitled NSFNET and this incorporated the modern day standard protocol of the

Internet TCP/IP (Transmission Control Protocol/Internet Protocol) and laid the path for future expansion, into what we know regard as the modern day Internet [438].

The WWW is part of the Internet and was developed in the early 1990s at CERN in Switzerland to include a user friendly graphical browser enabling more rapid access and manipulation of multi-media documents located elsewhere upon the Internet [439]. The Internet today, consists of thousands of networks connected together from continent to continent by a very high-speed network backbone. This backbone is run, in the large, by the world's large telecommunication companies providing high bandwidth channels between countries. Inter-country networks are then connected to this backbone servicing smaller networks within single countries. This hierarchy is repeated and has potentially few expansion limitations. This methodology creates the 'Web' of networks that span the globe and facilitates e-mail, web page access and business transactions [436].

From a user population of only a few thousand, situated primarily in academia, the Internet has currently grown to a user base of around 450 million and is predicted to reach 700 million by 2004 [441]. Internet traffic is rising at about ten times the rate of international voice traffic, with around one billion people having at least one telephone number in the year 2000 [441]. Presently, there are around 32 million global web-sites or 'domains', with nearly 26 million company or '.com' registrations [442]. Initial research focussed upon the Internet's ability to offer an alternative marketing tool, allowing some enterprises to make direct connections with their customers for the very first time, through corporate 'home pages' [443]. Nowadays, the potential of the Internet is seen as so much more, with the opportunities that business-to-business transactions and electronic commerce may bring. Over the next few years, it is predicted that business-to-business commerce will substantially outgrow business-to-consumer activity on the Internet [408].

Electronic commerce can be defined as 'the ability to perform transactions involving the exchange of goods or services between two or more parties using electronic tools and techniques' [444]. It can offer many advantages over more traditional paper-based commerce:

- ◆ It provides the customer with more choices and customisation options by better integrating the design and production processes with the delivery of products and services [444].

- ◆ It decreases the time and cost of search and discovery, both in terms of customers finding products and services and enterprises finding customers [444].
- ◆ It expands the marketplace from local and regional markets to national, international and global markets with minimum capital or resource outlay [444].
- ◆ It can facilitate increased customer responsiveness, on-demand delivery and payment [444].

The 'Electronic Commerce for SMEs' initiative launched by the G7 countries in February 1995 is embedded into the G7 initiative 'Information Society' and has worked to summarise the high priority issues holding up the acceptance of electronic commerce among SMEs across a number of geographies and industries [445]. Three electronic arenas can be distinguished for SMEs, Table 2.9.

Arena	Description	Technology/Examples
Business-to-consumer	<ul style="list-style-type: none">• Consumer access to information, products and services via electronic channels• Marketing• Electronic payment schemes	<ul style="list-style-type: none">• Bodensee Mall / Virtual Shopping (Internet)• Electronic Catalogues• Home banking
Business-to-business	<ul style="list-style-type: none">• Company networks and facilities and business-to-business electronic links• Orders, Invoices, Payment	<ul style="list-style-type: none">• Automated trading systems• Electronic Marketplaces (EDI, e-mail, extranets, web portals)
Business-to-administration	<ul style="list-style-type: none">• Electronic communication with administrative bodies	<ul style="list-style-type: none">• Denmark: Electronic tendering for government contracts (EDI, e-mail)

Table 2.9: *SME Electronic Commerce Areas, Booz-Allen and Hamilton [445].*

It is further proposed, by Booz-Allen and Hamilton that SMEs can deploy four different types of electronic commerce, with increasing value-added from a pure information access to the execution of transactions:

1. Substitution: Substitution of traditional forms of communications e.g. e-mail instead of fax / phone, multimedia for face-to-face [445].
2. Information Access: Capture and management of business documentation and information, e.g. access to remote on-line databases [445].

3. Business Process Management: Enabling new ways of performing business processes within enterprise boundaries, e.g. automated stock control [445].
4. Inter-enterprise / Consumer Business Process Management: Enabling new ways of performing business processes that extend beyond the corporate boundary into the Extended Enterprise, e.g. electronic distribution channels [445].

A recent survey [446] highlights the potential impact of electronic commerce for SMEs. It is quoted that 70 % of manufacturing SMEs already are, or intend to use the Internet to sell products and services. This is opposed to 80% and upwards for the transport, communications and retail sectors. The main reasons for manufacturing SMEs moving towards an Internet sales channel are cited as the ability to reach new markets / customers, improve communications and achieve cost savings. For those SMEs, which were already using the Internet, the principal uses were detailed as undertaking marketing and research, together with improving communications with suppliers and customers. Additionally, the main barriers for delaying Internet trading were identified as lack of demand, security, complexity and the need to change business processes. The main demand issue noted by the respondents seems to contradict results of other research [447] [448] which find there is enormous potential to be realised from the Internet. Few of the SMEs surveyed had considered the tax and legal implications associated with electronic commerce [449] but, had begun to the perceived main issues of consider, security, entrants from competitors and price visibility / transparency.

The characteristics of electronic commerce adoption, far from being uniform across the economy, vary across manufacturing sectors as well. Some areas such as the automotive and high-tech manufacturing industries appear to be largely taking the initiative in driving electric commerce adoption, where potentially powerful business benefit draws many partners together, through mediums such as extranets. Conversely, consumer packaged goods manufacturers are significant stakeholders in driving e-commerce initiatives, where vertical marketplaces and collaborative web portals are used [450].

The main focus for manufacturing SMEs seems to lie with business-to-consumer and business-to-business transactions [451]. This can be attributed to the fact that world wide business-to-consumer and business-to-business electric commerce

are forecast to reach around \$245 billion [452] and \$327 billion [453] respectively, by 2002. Keeney [454] presents a study upon the value of electronic commerce to the customer. This considers the use of a value proposition [455] to characterise the combination of end result benefit and price to a perspective customer from purchasing a particular product. Ghosh [456] provides an overview of the Internet as a new channel for commerce, stressing the point that managers cannot afford to avoid thinking about the impact of electronic commerce upon their business.

The use of the Internet and electronic commerce are clearly an attractive proposition for the manufacturing SME. Enterprises are already beginning to consider how to achieve business benefit from electronic trading as some of the barriers, such as security and complexity, are being overcome. However, issues such as legislation and taxation, may not be given the level of consideration they require [446]. To achieve success in the new electronic market arenas, it is predicted by the Gartner Group [457], that SMEs may have to spend nearly half of their IT budgets on updating their infrastructure, processes, organisation and customer / supplier relationships to facilitate the necessary strategic change.

2.5.3 Networking

As enterprises strive to achieve a global manufacturing capability they must acknowledge the value and substantial support that IT and network systems can bring. The nature and trends in the global marketplace mean that to overlook the recent developments in IT communications could be seen as folly [458]. The requirement of a suitable form of communications network can be seen as one of the first decisions to be made when implementing a global manufacturing strategy. It is also a decision that must be reviewed frequently, as the speed of change in data communications is very rapid and the enterprise's requirements will alter as the scope of its global operations increases [459].

An IT network can be viewed as being 'a collection of nodes that can communicate with each other via transmission lines, linking office automation, design and manufacture, management workstations and systems with the shop floor, in order to be more profitable than the competition', [460]. The key elements that will lead to success in any enterprise are the generation, transmission and processing of information in a high speed, reliable and accurate, manner. These should be largely

based on a widely agreed and implemented set of data communications standards. This is to ensure that a high level of IT integration can be supported between the various manufacturing functions or processes and that the systems will stand the test of time.

A key organisational issue in regard to deploying enterprise network structures can be seen as being co-ordination [409]. Improved co-ordination technology can have three knock on effects, Malone and Rockart [461]. A first order effect of reducing co-ordination costs is the substitution of IT for human technology. A second effect of reducing co-ordination costs is an increase in the overall amount of co-ordination used and finally, the third order effect of reducing co-ordination costs is a shift towards the use of co-ordination intensive structures. Mintzberg's adhocracy structure [234], further popularised by Alvin Toffler in his book 'Future Shock' [462], describes an enterprise that can be readily supported by IT networking. The adhocracy is extremely co-ordination intensive due to the large amount of lateral communication. New media such as electronic mail, computer bulletin boards and video conferencing can make the co-ordination easier, therefore, enabling the adhocracy to function more easily. The relative costs for hierarchies and markets show a delicate balance between the two, Figure 2.28.

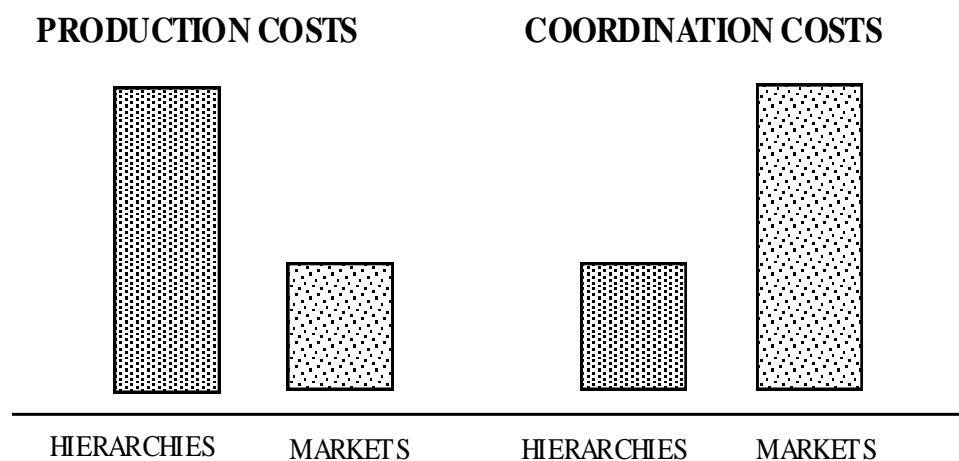


Figure 2.28: *Relative Costs for Hierarchies and Markets, Malone and Rockart [461].*

The first IT networks were time-sharing networks that used mainframes and attached terminals. Both IBM's System Network Architecture (SNA) and Digital's network architecture implemented such environments. Local Area Networks (LANs) evolved around the PC revolution. LANs enabled multiple users in a relatively small

geographical area to exchange files and messages, as well as access shared resources such as file servers. Wide Areas Networks (WANs) interconnect LANs across normal telephone lines and other media such as fibre optic cables thereby interconnecting geographically dispersed users. Today, high speed LANs and switched internet works are becoming widely used, largely because they can operate at very high speeds and facilitate the deployment of high-bandwidth applications such as voice and video conferencing [438].

It is proposed that current networking technology and the Internet infrastructure will not be able to support increased bandwidth and speed demands placed upon them in the short-term, Siebel and House [435]. Current rates of network and server improvements though, suggest that the performance differential should soon start to narrow. Contemporary network router technology from companies such as Cisco Systems and 3 Com allows the delivery of up to 500,000 packets of data per second. The next generation of routers that are currently undergoing development will be able to deliver as much as 30 million packets per second. Additionally, Internet Service Providers (ISPs) presently utilise T1 (1.5Mbps) network connections to deliver Internet services into corporate IT systems, with T3 (45Mbps) serving as their national backbones. Today, these older technologies have been surpassed, with corporate networks now transmitting over OC-3 (155Mbps) optical cables and ISP international backbones using OC-12 (622Mbps) capacity, with the further implementation of OC-48 technology, operating at 2.4 billion bps, being available in the near future [435].

Two network protocol architectures have served as the basis for the development of interoperable communication standards: the TCP/IP protocol suite and the Open Systems Interconnection (OSI) reference model. The OSI model is a widely accepted, seven layer architecture of communications functions, that was developed by the International Organisation for Standardisation (ISO) to serve as a framework for the development of communication protocol standards [463]. In terms of networking the following 10 methodologies are regularly used, Tucker [464]:

1. Circuit switching
2. Packet Switching
3. Ethernet
4. Token Ring

5. Fibre Distributed Data Interface (FDDI)
6. Fibre Channel
7. Integrated Services Digital Network (ISDN)
8. Asynchronous Transfer Mode (ATM)
9. Frame Relay
10. Virtual Private Network (VPN)

Implementing a global IT network for an enterprise is no simple task. Many challenges must be faced, especially in the areas of connectivity, reliability, network management and flexibility. Each area is a key in establishing an efficient and effective solution. The challenge when connecting various systems is to support communication between disparate technologies, whilst at the same time addressing the primary concerns of security and extensibility [465].

2.5.4 Manufacturing Business Systems and ERP

Soliman and Youssef [467] comment, 'Recent developments in IT such as the Internet, ERP systems and knowledge management systems necessitate the use of these technologies in order for next generation manufacturers to co-evolve and survive on the new business landscape'. Weston [468] proposes, the notion of a Manufacturing Business System (MBS) to represent the primary IT system of an enterprise which has ongoing responsibility for determining the overall purpose of internal enterprise systems and for planning, controlling and observing their interoperation and performance, Figure 2.29.

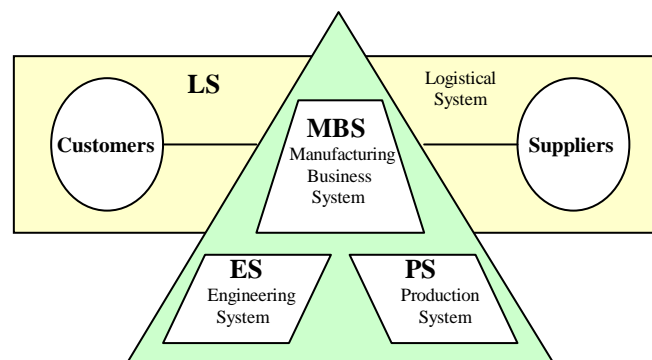


Figure 2.29: *Scope of a MBS within a Manufacturing Enterprise, Weston [468].*

A MBS can be further seen as a highly complex and organic, collection of manufacturing business sub-systems, that support the three meta life-phases and 'What, How and Do' [148] activities of an enterprise. The sub-systems can comprise complementary IT such as ERP, Advanced Planning and Scheduling (APS), Electronic Data Interchange (EDI), Business Intelligence (BI), Customer Relationship Management (CRM), Manufacturing Execution Systems (MES) and Intranets, which operate in a loosely coupled manner and are combined with appropriate groupings of enterprise personnel [469]. Current MBS deficiencies are cited as:

- MBS conform to semi-generic and idealised models of requirements and solutions rather than being uniquely engineered. Consequently, competing manufacturing enterprises are forced to use similar processes, systems and information models to realise products and services [470].
- MBS comprise teams of personnel and consultants, potentially with conflicting goals, who deploy a mismatch of methods and tools over various timeframes. As a result, manufacturing business sub-systems seldom operate toward enterprise goals, tend to compete for resources and mutually constrain each other's achievable states [471]
- As manufacturing enterprise size increases, complexity and uncertainty levels grow rapidly. If decomposition techniques are used to alleviate complexity problems then integration problems will arise and flexibility problems may soon follow [471].
- Current, IT manufacturing business sub-systems, generally appear as 'packaged' solutions and are inherently difficult to 'break into' and change. Current, techniques to facilitate sub-system interoperation and integration tend to leave existing elements largely unaltered, but typically introduce new front ends and glue that constrains unwanted achievable states [471].
- Contemporary methods and techniques used to change enterprise processes and systems can be deficient and very time-consuming / costly to apply. Due to the long time-scale over which MBS are deployed (6 months to 3 years) interim environment changes can make the original state change obsolete before it becomes operational [472].
- MBS practice does exploit well the human intellectual capital available to manufacturing enterprises. Nor does it account people as assets with knowledge and skills that can be exploited. This may be attributed to pressure to think short-term and be pragmatic, i.e. firefight [471].

- Present day MBS practice does not naturally generate common or holistic understandings of required enterprise states, behaviours and ways of moving between them. Key business processes and system changes are well known and documented. Indeed, it is even less likely the any manufacturing business sub-system will be used to record the knowledge used, decisions made and the resultant impact of a change process [471].

According to Hum and Sim [473], technological advancement, global competition and ever-changing customer requirements have lead to a constant evolution of competitive strategies. In this environment, MBS and next generation IT components have emerged as tools for achieving sustainable competitive advantage [467]. It should be concluded though that, although there is much scope for improving MBS concepts, methodologies and tools, it is unlikely that there will every be an ideal MBS that will serve all needs of all manufacturing enterprises.

The single largest sub-system or component to comprise a MBS may been viewed as an ERP system. ERP systems are packaged business software systems that allow enterprises to: automate and integrate the majority of business processes, share common data and practices across the entire organisation, and produce and access information in a real-time environment [474]. Whilst ERP systems are often described as MRPII systems with added functionality [15], a clear distinction needs to drawn between 'ERP as a philosophy' and 'ERP realised and implemented by current vendors such as SAP, Baan, JD Edwards, Oracle and Peoplesoft'.

ERP had its roots established in a book entitled 'Material Requirements Planning' which was written by Joseph Orlicky in 1975 [475]. The concept of MRP, invented by Orlicky, rapidly gained acceptance in the manufacturing community and was promoted by APICS (American Production and Inventory Control Society), together with well-known manufacturing professionals such as Goddard, Plossl and Wight [476] [477] [478]. In 1979, the concept of MRPII was developed by Oliver Wight [479] to try and integrate all decision support aspects for manufacturing into a single, standardised, database system. This name was well chosen, because it indicated the continuity from MRP to MRPII [9]. At this time the emergence of additional packaged software was seen for other important management functions such as accounting, cost analysis and logistics [480].

ERP systems further developed the scope of standard MRPII systems for new areas of manufacturing business, such as fixed assets management, shop floor scheduling and control, distribution, transportation, service, financial services, EDI, tracking, product data management and tracing of historical data for quality systems (ISO 9000), etc [9].

ERP may be seen as technological advance, not just an extension of MRPII. The forces that have initiated the development of ERP can be seen to be the same as those that are present throughout the whole of industry. These are the desires for increases in customer satisfaction, quality and variety combined with decreases in delivery dates, costs and global manufacturing enterprises. The ERP model acknowledges these pressures and proposes the requirements of how such a computer system could proactively support global trading, now and in the future, Knutton [481].

The ERP methodology still embraces MRP and MRPII as well as extending the scope of planning, implementation and control to higher and wider levels of capability. The benefits of an ERP system are that it is a multi-business, multilingual, multi-country system that can integrate into a high variety of existing PC, server and mainframe based systems [482]. Figure 2.30 details the scope of an ERP system.

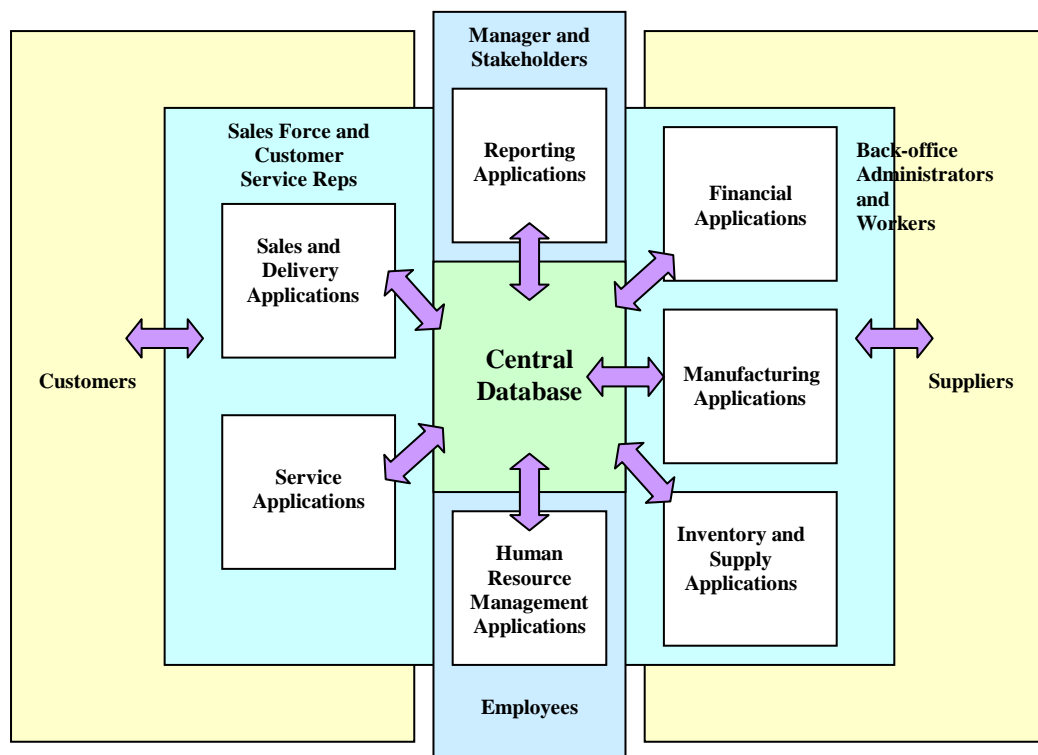


Figure 2.30: *Anatomy of an Enterprise System, Davenport [10].*

At the heart of the ERP system is a central database that draws data from and feeds data into a series of application modules supporting diverse business processes. Using a single database dramatically streamlines the flow of information throughout the enterprise. An ERP system is usually built from a number of modules, which can be classified, into three groups [483]. Basic modules, that are compulsory acquired when the client purchases the software (e.g. Accounting), Optional modules for specific functions (e.g. Warehousing), and Vertical modules which are specifically adapted for a particular customer need (e.g. EDI). Most vendor ERP systems rely upon client/server technology and generally utilise Oracle, Informix, DB2 and Microsoft SQL Server as the central database. The configuration of the software to suit the requirement of individual customers is a complicated process and requires a high degree of compromise between the way the way you want to work and the way the system will let you work. Also, a high degree of implementations have to undergo bespoke customisation to ensure a reasonable degree of business fit [10]. If standard ERP software is customised, two major problems can occur. One, package integrity can become difficult to maintain and support and secondly, the enterprise can become locked into the version release as it may be prohibitively expensive and difficult to upgrade [484].

The growth of the ERP market has been explosive and is predicted to continue, with research indicating that the market for ERP applications will increase from around \$13 billion in 1996 to \$66.6 billion in the year 2003 [485]. The cost of implementing a new ERP system for a large global enterprise can cost between \$50 million and \$500 million depending upon the scope of the implementation [10]. Table 2.10 presents a summary of the top six ERP vendors.

Company	Revenue 1999	Employees 1999	Web Site
Baan Company N.V.	\$634.8 Million	5101	www.baan.com
Computer Associates	\$5,253 Million	14,650	www.cai.com
J.D. Edwards	\$944.2 Million	5,669	www.jdedwards.com
Oracle Corporation	\$8,827 Million	43,8000	www.oracle.com
Peoplesoft Inc	\$1,429 Million	6,929	www.peoplesoft.com
SAP AG	\$4,794 Million	20,500	www.sap.com

Table 2.10: *The Top Six ERP Vendors [486].*

Whilst, the main vendors at this top end of the market have emerged with large consulting firms, such as KPMG and Accenture, to dominate the corporate market for ERP packages and consultancy. Further down the market scale, lower tier system vendors are extending and re-labelling their basic MRP and MRPII systems, containing integrated sales order processing, invoicing, manufacture and stock modules, as full ERP packages to try and acquire improved market share [487]. Although, this may be additionally driven by the fact that SMEs typically prefer a one-stop shop and do not have the IT resources or inclination to integrate systems from different suppliers, these actions may inadvertently be counterproductive to the real needs of SMEs [18]. By vendors tending to move in this direction, prior best-of-breed systems may be diluted and replaced with more generic solutions, further limiting SME choice [488].

ERP as a philosophy, stresses the importance of standardisation, integration and the co-ordination of human and technical resources to support global business plans, but as a system, it cannot 'manage all of a corporation's internal operations in a single powerful network', as some vendors and authors propose [489]. MRPII is introspective, looking at the control of an individual site in a reactive nature, whereas ERP looks, proactively outwards. In basic terms, MRPII might typically say 'since the order rate has changed, what is the best way of handling it?'. ERP might conversely take the approach, 'if / when we get this order, which site in which country has got the capacity and skills to manufacture the product at least cost?' [490].

Although, the web sites of each ERP vendor describe numerous implementation success stories, the academic community has previously paid little attention to ERP [9] and it is further reported that between one quarter and one half of ERP implementations fail [491], often with significant financial consequences for the enterprise involved. Bang and Olufsen experienced a total halt to deliveries for eight days at a cost of £8.5 million [7], whilst Hershey Foods Corporation was recently estimated to have lost \$100 million when their newly implemented ERP system did not go live on Halloween as planned [492].

In a recent ERP survey [493], it is noted that by the year 2002 at least 75% of the manufacturing enterprises surveyed would be using packaged manufacturing systems as opposed to 25% who used totally bespoke systems. The most important criteria when considering the purchase of a new package were considered to be:

1. Scope of functionality.
2. Best fit / ease of integration with the business.
3. Flexibility.
4. Large installed base / market share
5. Time taken for implementation.
6. Competitive pricing.

The primary drivers, leading to enterprises purchasing ERP systems are noted as business ones, not technological. Foremost amongst these is the need to reduce manufacturing costs and the need to reduce lead-times. Durmusoglu et al [494] present results from a survey of 260 Turkish manufacturing enterprises, who had implemented MRP/MRP II type systems, and conclude that these reductions may be achievable. On average, the seven enterprises, which returned data regarding business improvement factors, gained an increase in inventory turnover of 76%, together with reducing delivery lead-times by 29% and the average throughput by 23%. The limited response to this suggests that only a small number of enterprises were actually in a position to measure the performance of their systems. More recent work by Teltumbde [495] has concentrated on the evaluation of ERP systems. It suggests seven dimensions: Strategy-fit, Organisation Culture, Risk, Implementability, Flexibility, Costs, and Benefits should be applied to an assessment web when comparing ERP implementation. This work though does not really quantify or define measures for the possible performance benchmarking across industrial groups or types.

In respect of the SME community, ERP systems have been much overlooked as it has always been thought SMEs require software that is tailored to their particular requirements, rather than commercial software, which is predominately designed for larger enterprises [496]. Research and survey work presented by P. J. Armstrong and P. J. Coyle [15] suggests that SMEs have a desire to introduce computer-based information systems, such as ERP packages, but do not have sufficient in-house expertise. The option for SMEs to consider the implementation of MRP/ERP software should be encouraged, but this has to be at a relatively low cost. The implementation of ERP and electronic commerce may shortly become an essential pre-requisite for SMEs existing and becoming integrated into extended supply chains and vertical markets [497]. Little et al [498] [499] have sought to provide SMEs with a simple

software specification method for IT packages selection. This method is encapsulated into a software tool called SMEST (SME Support Tool) and is focused solely on software packages, as bespoke software development is not considered practical in SMEs due to their inability to describe their requirements and the degree of expense involved in developing tailored software.

Limitations of traditional ERP type systems have begun to be realised for ETO and MTO production strategies [487]. These do not fit into classic ERP systems because there is no way to determine exactly what to manufacture until the enterprise receives an order that specifies the unique combination of components that are to be converted into the finished goods. Forecasting such product variations using MPS can seem futile and there then, may be a temptation to return to re-order point systems near the raw material level. The future for basic MRP driven systems seems limited as the market demands of mass customisation, even shorter lead-times and higher throughput mean the level of sophistication required for production control is far higher than such systems can adequately cope with [500].

The future for ERP may be more as a transaction engine that is based around core processes, such as sales order and invoice processing, rather than as an all-round enterprise-wide solution. Ford [8] proposes that best-of-breed, or 'business growth' applications, such as electronic commerce, APS, or BI, could then be used to deliver additional functionality to key business areas. These business growth applications require three criteria:

1. Seamless Integration with the core transactional ERP system [8].
2. Enterprise-access to current information, including web-enablement [8].
3. Portability between ERP systems [8].

This direction is further supported by Mason [501], who takes a CIM vision and looks to the integration of lower-level production systems such as, System Control and Data Access (SCADA), Line Control (LCS) and MES, with ERP systems. Huang and Mak [502] have reviewed the use of the Internet to support product design and manufacture, using web-enabled decision support and CSCW technologies, but comment the web-based approach is just in its infancy. The absence of a rigorous and systematic approach to the development of web-based applications is cited as a major

problem, together with the fact the web is mainly regarded as an information medium rather than as an application platform. In a Dataquest survey [503] of 153 varied enterprises, it is revealed that two-third of the enterprises surveyed have made, their packaged application available over the Internet, or plan to do so. Additionally, Internet access to applications is significantly more widespread in large enterprises than SMEs. Almost 49% of enterprises with 10,000 or more employees provide Internet-based application access, but only 15% of enterprises with between 500 and 1,000 employees do so.

In response to the changes in the business environment and because of the new found limitations of existing solutions, ERP vendors and consultancies are now seeking to move their products and services further forward. Vendors such as SAP, Oracle, JD Edwards and Peoplesoft are currently adopting fast-track programs to add SCM, CRM and Supplier Relationship Management (SRM) functionality to their core systems [504] [505]. The challenges faced include extending business processes and applications to provide customer support; as well as supplier and partner support; manufacturing to demand and order; managing maintenance, repair and overhaul (MRO) operations; integrating the research and design function; together with making decisions in support of product life cycles [506]. Gartner [507] suggests that 'ERP is shifting from the foundational enterprise application to a key component of an inter-enterprise application-oriented environment'. The result is the emergence of what they term 'next-generation ERP' or 'ERP II'. An ERP II application approach emphasises outward-looking collaborative integration, which enables multiple enterprises to co-ordinate activities across the whole of the supply chain.

2.5.5 Complementary IT Systems

As described in the prior section, ERP systems functionality and scope, could be seen to fall short in a number of key areas. To combat this problem, additional specialised software vendors have sought to deliver complementary (bolt-on) software that can serve to meet modern day business imperatives, whilst at the same time allowing customers to build upon the investment in their core ERP packages. Concurrent to this, higher-tier ERP vendors, because of their market presence and financial power, have sought to acquire niche software vendors or develop partnerships to extend their

product and service offerings [8] [508]. This section aims to present a brief overview of the main complementary IT system in general use, which include BI, EDI, Intranets, APS, and CRM.

2.5.5.1 Business Intelligence (BI)

Business Intelligence (BI) tools or as they are more commonly called Executive Information Systems (EIS), tools have been around since the 1980s [509]. EIS are defined by Watson et al [510] as, 'a computerised system that provides executives with easy access to internal and external information that is relevant to their critical success factors' and can assist in generating considerable cost savings for an enterprise [511]. Typically, BI tools have the following characteristics [512]:

- An easy to use and maintainable, graphical interface.
- Integrated capabilities for varied data access, security and control.
- On request 'drill-down' capability to lower levels of detail.
- Depiction of enterprise key performance indicators.
- Data analysis and advanced report generation.
- Statistical analysis tool for summarising, grouping and re-structuring data.

The key to a successful BI solution is the integration not only of data and information from a variety of sources, both within and outside the enterprise, but also of the decision-makers themselves. BI tools can only become a strategic weapon when business users are able to obtain answers to questions in a time frame consistent with the requirements of a dynamic and agile enterprise [513]. Palvia et al [514] further comment that such system deployments should be of a global dimension in order to understand more readily the constraints that enterprises operate under when trying to compete globally.

For today's enterprises to succeed they need a level of agility that can only be achieved through decision makers who are able to manage multiple plans in parallel, switching between alternative scenarios in near-real time reaction to new information. BI tools should be self-learning and capable of predicting the users needs. These problems, together with the rigidity of the user interface are BI software greatest failings [513]. BI tools are superimposed onto ERP systems, because underlying data

may only be accessible in standard paper-based lists and the development of bespoke reports can be prohibitively expensive [8].

Data warehousing has the capability to, extend the BI concept and provide an accurate and all embracing data store, upon which all reporting can be based. A data warehouse is said by Jarke et al [515] to be 'a collection of technologies aimed at enabling the knowledge worker (executive, manager, analyst) to make better and faster decisions.' An alternative definition is proposed by Inmon [516], 'A data warehouse is a subject oriented, integrated, non-volatile and time variant collection of data in support of management decisions'. In essence, a data warehouse is expected to have the right information at the right place, at the right time, with the right cost to support the right decision.

In the traditional view, data warehouses provide large-scale caches of historic data. They sit between information sources gained externally or through online transaction processing systems (OLTP), and decision support or data mining queries, following the vision of on-line analytical processing (OLAP). Three main arguments have been put forward in favour of this approach [516].

1. *Performance and safety considerations:* The concurrency control methods of most Database Management Systems (DBMS) do not react well to a mix of short update transactions (as in OLTP) and OLAP queries that typically search a large portion of the database. Moreover, the OLTP systems are often critical for the operation of the organisation and must not be in danger of corruption by other applications [515].
2. *Logical interpretability problems:* Inspired by the success of spreadsheet techniques, OLAP users tend to think in terms of highly structured multidimensional data models, whereas information sources offer at best relational, often just semi-structured data models [515].
3. *Temporal and granularity mismatch:* OLTP systems focus on current operational support in great detail, whereas OLAP often considers historical developments at a somewhat less detailed granularity [515].

The initiation of data warehousing was initially a consequence of the observation by Inmon and Codd in the early 1990s that operational-level (OLTP) and decision support applications (OLAP) cannot coexist efficiently in the same database environment,

mostly due to their very different transaction characteristics [516]. It is also noted that two very different types of data are involved, primitive or operational and derived or decision support. Primitive data is detailed data used to run the day to day operations of the company. Derived data is the data that is summarised or otherwise calculated to meet the needs of the management of the company. Live versus historical. Vendors agree that data warehouses cannot be off-the-shelf products but must be designed and optimised with great attention to the customer situation [517]. A typical data warehouse structure can be seen in Figure 2.31.

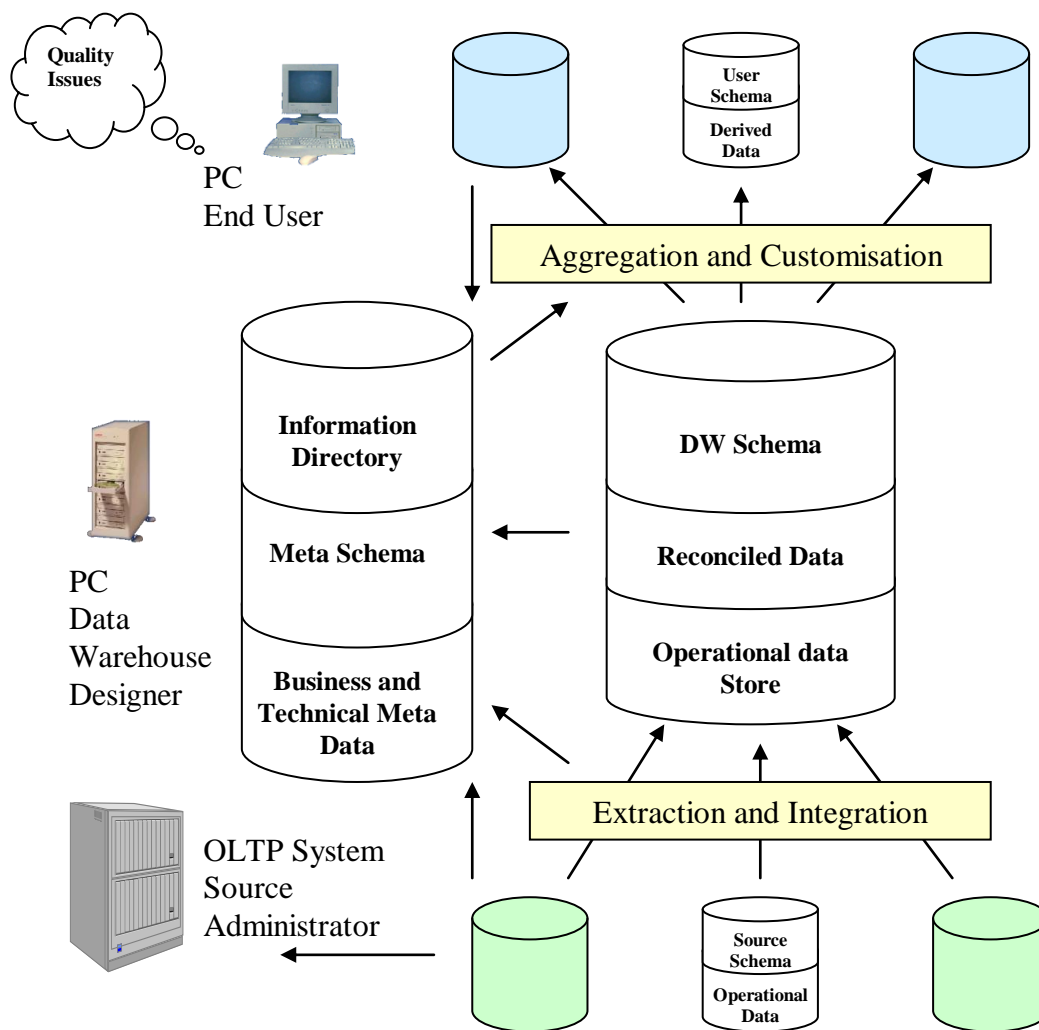


Figure 2.31: A Generic Data Warehouse Architecture, Jarke et al [515].

There are two approaches to the implementation of a data warehouse, top-down or bottom up [518] [519]. Top down is generally more rapid and cheaper, giving the users a generalised global view of their enterprise; where as bottom up can be costly as

it based upon a rigorous requirements definition phase. There can be seen to be three types of different data warehouse architectures [520]. Centralised, where there is only one central data location that stores all necessary data for business analysis. Federated, where the data is logically consolidated but stored in separate physical databases, at the same or different physical locations and finally Tiered. This is where the central data warehouse is also physical, but in addition to this there exist local datamarts on different tiers. A data mart can be seen as a small, local data warehouse [515]. These store copies or summaries of the previous tier, but are not detailed data repositories as in a federate architecture. The design of a data warehouse is a difficult task and several problems can be seen:

1. They have to come up with the semantic reconciliation of the information lying in the sources and the production of an enterprise model for the data warehouse [521].
2. A logical structure of relations in the core of the data warehouse must be obtained either serving as buffers for the refreshment process or as persistent data stores for querying, or further propagation to datamarts. [521].
3. Hardware selection and software development is another process that has to be planned by the data warehouse designer [522].

2.5.5.2 Electronic Data Interchange (EDI)

Electronic Data Interchange (EDI) is a simple concept that is defined by Linthicum [523] as, 'a standard for sharing information between trading partners in support of supply chain integration'. EDI has been in limited use since the 1960s, but it is over the last decade that its popularity has dramatically increased. This can be attributed to the level of interest currently focussed upon electronic commerce and the fact that IT and telecommunications cost have fallen rapidly. Today, more than 200,000 US enterprises use EDI, to execute at least one transaction type, and range from large global companies such as Motorola to very small electrical suppliers that employ around 15 employees. Document transaction types range from sales and purchase orders to advance shipment notes and invoices [524] [525].

EDI makes use of cross-industry standards such as EDIFACT, Tradacoms and ANSI X12, in conjunction with Value-Added Networks (VAN). A VAN is a message forward, store and retrieve network service that is provided by companies

such as GE Information Services and Sterling Commerce. Typically, each VAN operates to a pre-determined standard, but can interconnect with any number of other VANs. The benefit of using a VAN are that it provides access to established trading communities, transaction costs are relatively small and the data is transmitted securely and reliably [526]. The potential benefits, problems and issues of implementing EDI are summarised in Table 2.11.

<i>Benefits</i>	<i>Problems</i>
Faster transaction turn-around	Legal
Less paperwork	Security
Savings in staff time	The need for standards
Fewer errors	
<i>Issues</i>	
Reduced inventory versus shift in inventory responsibility	
Faster incoming payments versus faster outgoing payments	
Closer links with customers versus being tied to suppliers	

Table 2.11: *Benefits, Problems and Issues, Hendry [527].*

Interoperability, standardisation and the concept of open systems are the crucial elements that will allow all the different pieces of a global enterprise, regardless of size, to communicate effectively. These permit telecom and IT systems from different manufacturing enterprises to communicate leading to large-scale advantages for users and the creation of a truly global market [528].

To integrate EDI into ERP systems, there generally exists a two-stage process. Firstly, the EDI message has to undergo basic translation into work able data files, then secondly, these data files need to be validated, before they are effectively loaded into the ERP system. The outgoing process is similar, but in reverse [526]. ERP vendors such as Peoplesoft [523] have developed generic interfaces for many standard business transactions. Although, these interfaces can be utilised for more generalised data integration purposes, such as loading internal stock transactions, specialised integration and validation programs (EDI Adaptors) may have to be written allow to the data to be loaded effectively. The most important factor concerning the use of EDI is its costs. These can be further broken down in to:

- *Implementation Costs:* The purchase of hardware and software, installation of telephone lines and communications equipment, training and management time [527].
- *Running Costs:* The rental of telephone lines, call or packet charges, other communication costs, equipment maintenance, help desks and continuous staff training [527].
- *Other Re-organisation Costs:* From new forms and stationary to office moves and redundancy payments [527].
- *Study and Decision Making:* One of the most important and often the most hidden costs is that of researching the market, deciding whether or not to use EDI and selecting a system appropriate to the needs of the organisation. Although consultants can undoubtedly help here, they too represent a cost [527].

There are many other benefits that should be considered that arise from creating more efficient operations, such as direct links with customers and improved management controls. These, though, not real savings can nevertheless affect the decision to implement an EDI system [529].

To alleviate some of the cost and implementation barriers of traditional EDI systems, recent academic and industrial research has moved to the use of the Internet and XML (Extensible Markup Language) as a simpler alternative [467]. XML is a specification of the World Wide Web Consortium that standardises how to define documents containing structured data, for transmission over the Internet [530]. Whilst, the Internet route clearly offers the potential to significantly reduce data transmission cost, through the removal of VAN services. Threlkel and Kavan [526] stress that users are reluctant to embark upon this transfer because of the concerns of, security, newness of technology, too little legislation, lack of Internet standards, reliability and security. Whilst, Chi and Wolfe [277] have suggested a method of using XML within the supply chain, its wide-spread uptake among the manufacturing community is still very limited.

2.5.5.3 Intranets

Today, people from both business and academic communities are reviewing the potential business benefits that can be derived from the deployment of telecommunications technologies such as Intranets, [531]. However, due to the immaturity of this technology, most research and implementations have been limited to

larger enterprises. There exists little informative work on the adoption of Intranets by SMEs, and the literature on Intranet adoption by small enterprises is very limited [532]. Survey work undertaken by Buonanno et al [533], identified that very few SMEs were making use of Intranets, and that there was little support for the deployment and utilisation of such systems. Cultural and organisational reasons are cited as a major factor for this. The most concise definition of an Intranet [534], is '*deploying Internet technology inside an organisation*'. An Intranet consists of building blocks:

- A networked computer infrastructure such as a local area network (LAN) [113],
- A communication protocol such as TCP/IP (Transmission Control Protocol / Internet Protocol) [113], and
- A Web Server which, hosts web pages and handles all the communications with clients that access the server through a *browser* [113]. Figure 2.32 shows a sample Intranet infrastructure.

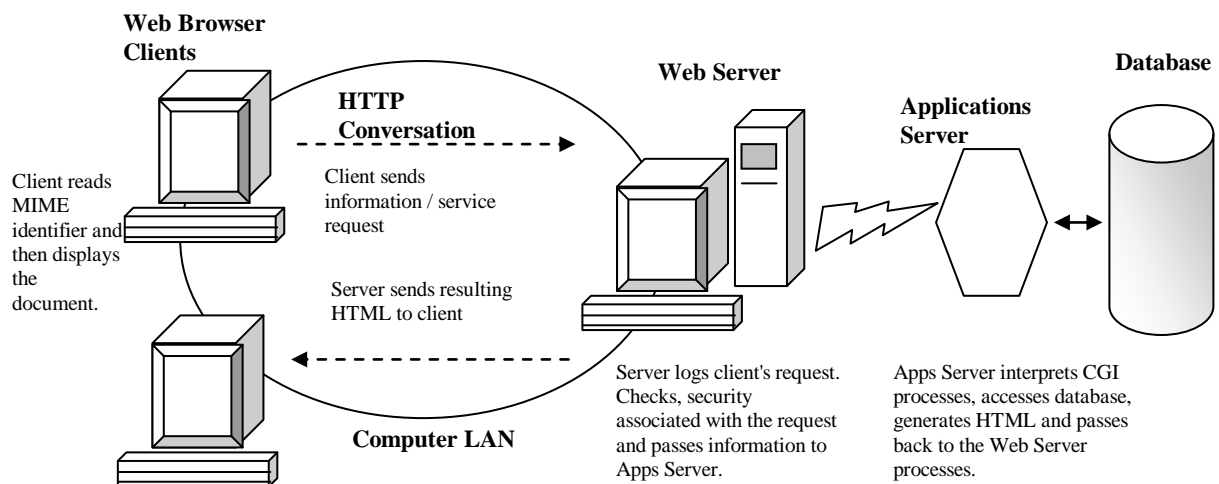


Figure 2.32: *Sample Intranet Infrastructure, Denton et al [113].*

Large enterprises such as Glaxo Wellcome [534] and BT [535] are already using these technologies to boost profits and improve customer service. The International Data Corporation's (IDC) "*Return on Investment (ROI)*" study revealed that Intranet applications in the enterprises that they had studied had yielded, on average, a ROI ranging from 52% to 2,522%, [536]. The Intranet benefits can include ease of use,

lower desktop costs, a single intuitive interface, links with legacy applications and databases, together with widespread industry support. Intranets have previously been utilised to assist in BPR and quality management system implementations, but technical issues related to security and maintainability are often cited as major problems [537].

2.5.5.4 Advanced Planning Systems (APS)

As IT has become increasingly cheaper, and the cost of maintaining inventory grows, there is a trend towards focusing on SCM. This move is now including the implementation of Advanced Planning and Scheduling (APS) systems to assist enterprises with managing their supply chain as a whole, as traditionally enterprise management has previously placed large emphasis upon optimising lower-level production and distribution business units [538].

APS systems are packaged software applications that have been developed to address many shortcomings within MRP/ERP type systems and can be said to build upon specialised finite resource planning systems that have been in general use for some time now [383] [539]. The major weakness of MRP/ERP systems, with respect to planning include:

1. The assumption that supply lead-times are known constants, and do not vary with flow [540].
2. The system requires fixed processes of routings, ignoring alternative processes that could be used [539].
3. The sequencing logic priorities orders only by period or date, when other options for example highest priority, minimal tool change, may be preferred [539].
4. All work is loaded under assumption of infinite capacity, when working capacity is always constrained by time and available resource [539].
5. The process of regeneration takes considerable time to calculate, review and process the recommended actions, this leads many enterprises who only regenerate their requirements on a once a week or month basis, when the industry it operates in is seeking daily to be passed over [539].

APS systems typically, reside above ERP systems and extract data from them, before applying model-based formula and algorithms to arrive at a feasible plan or schedule. Such systems may simultaneously consider all relevant production constraints including

machines, raw material, items, employees, set-up times, tooling, electricity due dates, together with work calendars and transportation times before producing new or re-scheduled plans in very short timeframes, i.e. minutes not hours [541]. This type of planning can be undertaken very rapidly because all the current information is held in the memory of the computer, avoiding repetitive read and write transactions from a database [542]. According to the Institute of Operations Management APS systems have a number of features in common:

- All are decision support tools. APS systems provide information upon which people make decisions [543].
- All are tools and techniques to help manage complexity. For fast moving environments with large numbers of items, order, machines and people, APS can provide significant planning assistance [543].
- APS does not include non-optimising planning approaches [543].
- Most can provide visibility of and compute plans and schedules for multiple simultaneous variables, such as resources and demand. Optimising criteria are generally user-defined and contained within a planning environment model [543].
- Most systems have a graphical interface for data presentation [543].
- APS systems are not transaction systems, that is, they prepare plans and schedules but do not provide facilities for recording or instigating material movements or issues [543].

An APS system can be seen to be a dedicated planning tool. It does not replace the ERP systems, but rather it sits upon them and works with them, in a closed loop. APS can provide planning capabilities across the supply chain, which, the ERP systems then executes and feeds the results back to the APS [538]. The benefits of APS can be realised over the total supply chain, even if ERP systems or independent data sources are not integrated, due to the use of 'neutral' file formats such as CSV (Comma Separated Values).

Whilst AMR research [539] suggest that enterprises who implement APS solutions can achieve ROI of between 30 and 300%, one of the key benefits of utilising such systems is an extension of the Available-to-Promise (ATP) concept. This is where, upon the receipt of an order, product availability and re-planning can be immediately triggered across the whole of the supply chain, thereby giving improved data accuracy rather than having to await, the next MRP cycle. Additionally, APS

system can be integrated with electronic commerce applications upon the Internet to give customers improved response times to product requests [540].

APS can offer planners a lower-level of time granularity, that can assist JIT processes to become more of a reality, but as most computer systems they are only as good as the data that is feed into them [543]. The completion of an accurate business model within the APS, the accuracy of shop floor data and timeliness of the data loads into the APS system are major concerns. In a US department of defence study [544], errors for key-entry data were found to be 1 for every 300 characters entered, against 1 for every 1,000,000 whilst using barcode readers.

Whilst it appears that APS can offer enterprises, with mature supply chains and system implementations, valuable benefits it is argued [545], 'To be effective, scheduling software doesn't need to be better than the expert conscientious human planner, only better than the average over-worked planner found in industry'.

2.5.5.5 Customer Relationship Management (CRM)

Customer Relationship Management (CRM) may be seen as a new breed of software by some [8], much like APS, but it can be alternatively considered to be a business strategy, designed to optimise profitability, revenue and customer satisfaction [546].

To implement or apply CRM, enterprises are required to implement collaborative processes and technologies that support customer-business integration regardless of the interaction type, i.e. field sales, retail sales, resellers, partners, direct mail, fax, call centres and the Internet. Until recently, software support has only been targeted at individual interaction types such as field sales or fax, but now CRM packages have emerged, such as Siebel and Clarify, to provide support for more extensive arrays of transactions, covering sales, service and marketing [508]. Additionally CRM applications can be closely integrated with standard ERP systems. Typical, functionality provide by CRM applications include:

- Opportunity Management System: Modelling steps in the selling process and including workflow capabilities, to allow enterprise managers to view the next steps required to complete transactions [547].
- Sales Configuration System: To enable enterprises to configure products, pricing, promotions, services, financing options and market bundles [547].

- Partner Relationship Management: To enhance an enterprise's ability to work with and leverage supply chain partners to better market, sell and service customers [547].
- Interactive Selling Systems: These are customer facing technologies and applications to allow customers to conduct transactions without a sales person [547].
- Incentive Compensation Management: To administer and manage compensation plans, quotas, crediting and adjustment while processing commissionable transactions. These may also include, capabilities for 'what-if' modelling and financial reporting on a deal-by-deal basis [547].
- Content Management: to allow enterprises to view and access various different types of media. (e.g. text, graphics, animation and video) [547].
- E-service: Applications that empower customers, partners and prospects to undertake self-service interactions with the enterprise via the Internet, Intranets or Extranets [547].
- Call Management: To log incoming telephone calls and transactions, and manage the transaction from initiation through to closure [547].
- Field Service and Despatch: To provide support for call management, workforce forecasting and scheduling, contract management, warranties, entitlements, depot repair/overhaul, technician despatch, service parts, defect tracking and reporting, etc [547].
- Personalisation: To continually adjust end-user profiles to match content and services. Business rules may be applied to select the most appropriate solution to customers based upon recorded preferences [547].
- Datamart / Analytical: Using software to produce ad-hoc queries, reports and analysis to support strategic decision-making [547].
- Campaign Management System: A database management tool to help the sales and marketing managers to design and execute focussed selling campaigns and monitor them over time [547].

Few CRM vendors can deliver across all of these 12 criteria and it is important to note that industry-specific functionality, e.g. promotions management for consumer packaged goods or ATP capabilities for manufactures are not included. While it is acknowledged that CRM applications can assist enterprises that have to service high numbers of customers and partners through multiple sales channels, there is little point in focussing upon CRM while undertaking an aggressive acquisition strategy [548]. Currently, SMEs are resisting the trend to implement CRM solutions because they are perceived to be too complex, expensive and inherently risky. This though, is against

recent survey findings that identify increases of 11% revenue, 16% customer retention, 19% employee productivity and 20% in customer satisfaction [549].

2.5.6 Software Development and Implementation

The development and implementation of software systems is a structured and complex activity. Various steps are involved such as, software design, programming, validation, deployment and evaluation [464]. In recent years the impact of the year 2000, European monetary union and a skills shortage, together with business transformation programmes such as BPR and electronic commerce, have placed great stress upon IT [550]. These threats though have realised some wider IT benefits [551]. Firstly, the weaknesses in current software development and support practices have been promoted to an audience outside of software engineering and academia. Secondly, the scale and complexity of software maintenance has shifted the economic argument to the replacement of many legacy systems and thirdly, resources have been made available for research aimed at prevention of similar problems in the future.

Software development to some, still remains a 'craft' industry, beset with problems of delayed and cancelled projects, inadequate quality, long cycle times and high costs [552]. Software packages have not been adequate alternative to bespoke deployments, often involving long, costly and difficult implementation projects and even more difficulties in integration and upgrading. Typical approaches to software delivery, Table 2.12, have been based upon a combination of the size and purpose of the project.

Sourcing	Build, Buy
Development Method	Rapid Application Development (RAD), Object Orientation (OO), Information Engineering
Technical Architecture	Client / Server, Distributed Object, Internet
Technology	COBOL, Computer Aided Software Engineering (CASE), Client/ Server 4GL,
Purpose	Tactical, Strategic
Size	Large, Medium, Small
Management / Ownership	Business / IT

Table 2.12: *Typical Approaches to Software Delivery, Andrew [552].*

For packaged ERP systems and ad hoc bespoke system structures, current practice is to specify overall system requirements by utilising a proprietary (to a management consultant or system integrator) consultancy method or framework [553]. This strategy may then be linked to the use of software engineering methods and further, to the use of IT vendor methods and frameworks for commissioning their specific software products [554]. Such an approach, from survey work by Barber and Weston [553], is said to be deficient and can lead to very high cost, long lead-time IT projects, that cannot readily facilitate change outside of their original scope.

As these methods and associated techniques, such as structured programming, structured analysis and design and an object-oriented approach have been tried, none have been seen to achieve the level of success desired, in term of cost, quality and time [555]. Research [556] based upon a selection of software development projects in 1996 showed that around 40% failed, 33% overran and only 27% were delivered successfully. These failure rates sustained an upward trend from previous years and can be seen to build upon the need for widespread software development and implementation practice change [557]. To undertake this change, the utilisation of software reuse and components [558], software agents [559] and Enterprise Application Integration (EAI) [523] techniques may be seen as a potential way forward.

The importance of software reuse lies in its benefits of providing quality and reliable software in a relatively short time period. These factors reduce the cost of software development and maintenance. Software reuse is particularly advantageous, because it can increase productivity, enhance standardisation, increase portability and contribute to the evolution of a common component warehouse [556]. Software components are defined by Szyperski [560] as 'binary units of independent production, acquisition and deployment that interact to form a functioning system' and can be seen to represent the middle ground between, completely bespoke software and standard packages. Although each component is a standardised product, with all the advantages that it brings, the process of component assembly allows the opportunity for significant customisation. Approaches to component-based software development currently include Microsoft's OLE/COM (Object Linking and Embedding/Common Object Model) and DCOM (Distributed Common Object model)/ActiveX, OMG with

CORBA (Common Object Request Broker Architecture) and SUN with Java Beans [557].

Software Agents can be traced back to the field of distributed artificial intelligence, where Hewitt [561] proposed the concept of a self-contained, interactive and concurrently executing object, which he termed an 'actor'. This object had some encapsulated internal state and could respond to messages from other similar objects. Agent software has now become a rapidly developing area of research and has been applied to many areas such as, e-mail management, analysis of buyer patterns and Internet document searches [562]. Nwana [562] additionally provides a detailed overview of agent research and proposes that seven types of agent exist: Collaborative, Interface, Mobile, Information/Internet, Reactive, Hybrid and Smart. Whilst, software agent technology can provide benefits to certain manufacturing scenarios such as distributed intelligent manufacturing systems [563] and business process management [564], social issues of responsibility, privacy, legality and ethics, require extensive consideration.

Linthicum [523] briefly defines EAI as 'the unrestricted sharing of data and business processes among many connected applications and data sources in the enterprise'. This means that packaged or 'stovepipe' applications such as SAP, Peoplesoft or Baan and bespoke applications can share data and processes without having to make substantial changes to the applications or data structures. Traditionally, middleware has provided a limited point-to-point approach to enterprise integration [160], whereas the new vision of EAI is different:

- EAI focuses on the integration of both business-level processes and data, whereas the traditional middleware approach is data orientated [523].
- EAI includes the notion of reuse as well as distributed business processes and data [523].
- EAI allows users who understand very little about the details of the applications to integrate the applications [523].

EAI can be applied at four levels, data, application interface, method or user interface to achieve the integration of many applications and data stores so that they provide value to one another. Process automation or 'workflow', may be seen as the next logical step forward, where a mechanism is defined for tying together existing

enterprise processes so that they support the flow of information and logic between them, obtaining the maximum amount of value from each other to support enterprise goals [565]. A goal of EAI is considered to be a 'zero latency enterprise', where any application or transaction has access to any other application or data store instantaneously, without restriction [566].

2.5.7 Critique - Information Technology Perspective

The key understanding that can be derived from this sub-section of the literature survey is the fundamental importance that IT now has in the global manufacturing environment. This can be applied to any manufacturing enterprise regardless of size, location or product type. IT now has the ability, especially since the advent of the Internet and the introduction of electronic commerce techniques, to radically influence the current and future directions an enterprise may take.

In relation to the deployment of MBS and contemporary ERP type systems several issues have come to the fore in recent years as initial deployments have matured and enterprise knowledge and understanding of their structure has improved. Whilst, this type of computer system has the ability to radically transform and efficiently automate generic business processes such as sales order processing and accounts, several deficiencies in this approach have now been revealed, which may restrict their further growth and uptake. Contemporary ERP systems are often beset by problems with implementation cost/time, flexibility, integration, management information retrieval, system performance and their ability to deliver a platform upon which enterprises can sustain competitive advantage. To a large degree, underlying integration problems have been further exposed by moves towards dispersed enterprise business units, the implementation of electronic commerce initiatives and shifts towards extended supply chains. In addition, SMEs have extensive problems in relation to degree of business fit, cost and access to skilled personnel.

ERP type systems are now being viewed as more of a core enterprise transaction system upon which best of breed, package or component, based systems are 'bolted' on. This has the knock-on effect of making integration and support problems even more widespread. Overall, the central design of ERP systems needs re-addressing to meet the contemporary business requirements of enterprises, in the context of a rapidly changing, customer and globally focussed environment.

CHAPTER 3

PURPOSE AND SCOPE OF RESEARCH

3.1 Introduction

This chapter describes the purpose, research objectives, scope, and investigation methodology of the work reported in this thesis. It introduces the overall concept of Business Strategy Driven IT Systems for ETO and MTO SMEs and the creation of an IT Route Map of which these aims form a significant part.

3.2 Background

'The manufacturing world is in permanent change. Nowadays it is moving from an economy of scope, to an economy of scale under a global economy for mass customisation' [3]. Modern manufacturing enterprises are organic, complex entities that must operate in uncertain environments. To be successful and achieve competitive success, they must exhibit the behaviours of agility and innovation [6]. These attributes must be inherent and evolve in the mindset of the enterprise's stakeholders, as well as its strategies, systems and processes. Each of these attributes may have a global focus.

ERP implementations are often combined with a BPR exercise [9]. This can lead to the replacement of a functional organisation with a more process-orientated structure, linked to work flows. Functional silos may be replaced by separated business units to achieve more focus and cost saving [78] [567].

For typical SMEs it is infeasible to adopt the classical large enterprise approaches to ERP system implementation and BPR, which include the constant realignment and reprogramming of IT systems to the latest business process change. As stated in the EPSRC Software Engineering for Business Process Change (SEBPC) call of 1996/97, '...the cost and delay of changing the installed IT to meet the changed business requirement is much too high.' Inefficient business processes might result if the full implementation of advanced business systems (e.g. an ERP packaged solution) remains at around a two year period for any SME. Implicit evidence arises because replacement cycles of less than 5 years are common. Notwithstanding the wider implementation of ERP systems within the manufacturing industry, '...relatively little attention appears to have been paid to ERP by the academic community' [7] [9].

Currently SMEs play a key role in modern, global economies. In the case of the UK, 99% of manufacturing companies have less than 500 employees and many form integral parts of larger organisations and extended supply chains [20]. SMEs are being squeezed from all directions. Their customers demand higher quality products and services; the larger enterprises, which the small enterprises supply, are demanding ever-higher standards in the quality components and service. SMEs find it difficult to respond to these pressures and achieve success in the contemporary business drivers of quality, speed and price, or '*better, faster, cheaper*' as they have many barriers to growth [33] [70] [568]. Descriptions in the literature about SMEs do not yet comprise a coherent body of knowledge [15]. There is a growing mass of literature concerned with various aspects of SMEs, such as strategy [569] [570] [571], IT systems planning and implementation [421] [499] [570] production planning and control systems [16], [572], together with technology transfer [85], but it is evident there is a gap in current thinking. For example, improved understandings about SMEs are required, a) to determine how to develop their position in the developing global economies, b) to define necessary requirements and possible solutions pertaining to next-generation IT systems, and c) to determine how to address the major issues arising from resource constraints.

Despite vendor claims that ERP systems are all encompassing enterprise IT solutions, they can only really act as a primary sub-system for a manufacturing enterprise and not a total, end-to-end solution that can generate a competitive response to internal or external requirements [9] [12]. Additional systems such as BI, EDI, APS and CRM are regularly superimposed onto ERP systems to provide extra business support in terms of effective management reporting, supply chain control and superior customer interaction, respectively. More generally, it is appropriate groupings of enterprise personnel who supply additional business support and competitive advantage, having the required attributes of knowledge and skill, which are then focused and enabled by ERP [468].

It is argued that the only way to master the complexity associated with engineering and continuously developing ERP and complementary enterprise systems is through the application of modelling techniques [9]. These systems can prove more effective, when used either individually or collaboratively, if their requirements and

configured solutions are better understood. With the aim of trying to manage this complexity, the fields of enterprise modelling [3] [167] [214], enterprise integration [202] [572] and enterprise engineering [140] [142] continue to develop. Enterprise engineering is concerned with intra and inter enterprise operations and with improving their efficiency and effectiveness [138]. The only way to achieve these goals is through gaining a better understanding of the problem (hence a key role for enterprise modelling), and provide the right information at the right place at the right time (thus necessitating enterprise integration). The current premise is that, it is from these evolving, enterprise engineering concepts, together with the utilisation of re-configurable, component-based systems, that next-generation manufacturing business systems will emerge [148].

3.3 Purpose

The purpose of this thesis is to investigate and document aspects of the notion that, *'Current ERP systems, their architectures and implementation techniques, do not adequately satisfy the contemporary requirements of ETO and MTO SMEs'*. The foundation of this notion is based upon five assumptions. These assumptions concern reported deficiencies about contemporary methodologies and technologies, and are summarised below:

- i) Common characteristics of ETO and MTO manufacturing can be determined and grouped together in the form of a 'reference model', which can be viewed as being a 'mass customisation', parent strategy. This reference model can help individual SMEs to identify critical attributes for success and/or survival. Common manufacturing strategy descriptions are becoming very important in a global context, but as yet do not readily lend themselves to ERP computerisation.
- ii) SMEs are fundamentally different from large organisations. To enable them to succeed and survive long term they have had to develop their own unique blend of systems capabilities, which recognise common barriers to growth because the operation (and change to the operation) of their business processes is inefficient due to technology, skill and financial constraints

- iii) The ERP system paradigm does not readily match requirements of process orientated organisations. Rather it can reduce the competitiveness of these enterprises by making them conform to semi-generic or idealised business processes and thus partially remove their source of advantage.
- iv) IT systems which are integral to most enterprise systems must change, evolve and adapt sufficiently rapidly to enact business growth. But the nature of contemporary ERP systems, their complexity, implementation methodologies and requirement for support personnel or consultants and the application within SMEs constrains, rather than enables ongoing change.
- v) Fundamental shifts in thinking and operations in business environments have exposed current limitations of ERP systems in terms of available scope and functionality. Enterprise systems now need to address and support more readily, globalisation issues, advances in electronic commerce, M&A activity and partnering.

This research study seeks to be timely in terms of the problems it will address and in the way it will reason about necessary methodology and technology that can overcome the key problematic aspects of (i) through to (v). SMEs need to implement and deploy current generation ERP systems so that they can manage processes effectively and compete globally. However, the parent enterprise and any of its constituent SMEs have to react to modern day business changes without the benefits of deploying personnel with skill to conduct large scale business analysis and IT systems design and implementation. Without such assistance senior enterprise managers may need to accept what ERP vendors and consultants pronounce as being required as they may not be able to 'see the wood for the trees'.

With this current situation in mind, the aim of this thesis is to assist SMEs to make a significant shift in understanding ERP system design and deployment so that they might achieve enhanced business performance and ultimately, improved financial attainment. The approach is to help develop a holistic view of the enterprise, in which IT systems play a key intrinsic part, rather than focussing such developments on IT departmental issues. The study also seeks to provide pointers for significant research into ERP system design and deployment for larger scale extended enterprises.

3.4 Research Objectives

The principle objective of this research is to *provide methodical support for enterprise management in ETO and MTO SMEs*. Hence, research is to be centred on understanding, specifying and assessing the use of a semi-generic, enterprise engineering methodology, which enables the effective development and deployment of IT systems, by better aligning IT systems operation to key attributes of business strategy and processes. The specific objectives of this research are to:

- (i) Identify outstanding issues and common limitations related to the design and deployment of manufacturing business systems within contemporary ETO and MTO SMEs.
- (ii) Define and develop the concept of Business Strategy Driven IT Systems.
- (iii) Specify an IT Route Map, comprising Business Model Template, Systems Architecture and Implementation Framework, to promote the development of agile and innovative business activity in SMEs.
- (iv) Assess the benefits gained through the application of Business Strategy Driven IT Systems concepts and the IT Route Map.

3.5 Scope of Research

This thesis is written as a partial response to issues and trends uncovered by participation in a Teaching Company Directorate Scheme, followed by the author's subsequent experience in industrial management and academic research. Additionally the research has been heavily influenced by work carried out on EPSRC Project GR/K50535 entitled, 'Enabling Methods, Tools and Utilities for Enterprise Integration' and on EPSRC Project GR/L27077 which investigated the use of IT tools to improve the manufacturing performance of metalworking SMEs. Table 3.1 lists the key areas of research study that impacted on thesis methods, solutions and findings.

3.6 Research Methodology

The methodology of this thesis work is based on a combination model of descriptive and experimental research as described by Allison et al [573] and Bickman and Rog [574]. From the notion proposed in section 3.3, descriptive research in the form of a literature review, industrial survey, and case studies are to be initially utilised to

examine the problematic situation. This can be seen as a valid approach because a clear statement of '*what is*' is an essential prerequisite to understanding '*why it is so*' and '*what it might be*'. The use of an industrial survey will be twofold, 1) it will assist the author in attaining a good understanding of the current status of advanced MBS implementations within SMEs and 2) it will reduce the common argument against the use of case study research alone. This is regularly manifested in the preconception that case study data is based upon qualitative data only, and therefore can lack precision and rigor.

Key Research Areas	Existing Academic Knowledge	Other Research and Industrial Knowledge Drawn Upon
Next Generation Manufacturing Business Systems	Contemporary Business Environment and Globalisation Principles	Computer Integrated Manufacture Principles, Architecture and Concepts
Strategy Led Development and Deployment of New IT Systems	Business Process Analysis, Re-engineering and Innovation Methodologies	Manufacturing and Information System Standards (e.g.: STEP, MANDATE, and COBRA)
Formulation of Semi-Generic Enterprise Models for ETO and MTO Environments	Enterprise Modelling Techniques and Reference Architectures (e.g.: UML, CIMOSA, GERAM, ARIS and PERA)	Vendor ERP Systems and Business Excellence Implementation Techniques (e.g.: SSA Basis, Oliver Wight).
Knowledge Representation Technologies to Underpin Systems Modelling Work.	Enterprise Integration Methodologies and Component-Based Systems Design	Manufacturing System Holons, Ontologies, Simulation and Related Tools (e.g.: TOVE, KQML and ProcessWise)
Small and Medium Sized Enterprise Resource Constraints, together with Effective Business Process Resourcing	Enterprise Engineering Concepts and Techniques.	Software Analysis and Design Methodologies (e.g.: SSADM, SADT, JSD, IDEF, Booch)
BI / EDI / Intranets / APS / CRM Requirements and Deployment	Distributed Object and Agent Technologies and Standards.	Human Computer Interaction. Knowledge Elicitation and Representation Techniques.
Rapid Application Development and Component-Based Design Techniques	MRP / MRP II / ERP Systems Theory	Web Technologies (e.g.: Browser, HTML, PERL and JAVA)

Table 3.1: *Key Research Themes*

Yin [575] defines a case study as a research strategy that 'attempts to examine a) a contemporary phenomenon in its real-life context, especially when b) the boundaries between phenomenon and context are not clearly evident'. Since the main thrust of this thesis work is related to the implementation of enterprise IT systems and only they can be implemented in a real-life context this approach seems clearly justified. To the largest extent possible and where appropriate, the methodological case study guidelines provided by Yin [575] and Robson [576] will be used. This work will aim to

set out accurate and adequate descriptions of the problem from which a firm hypothesis and experimental base can be founded

Whereas descriptive research seeks to answer the question '*What is?*' The second experimental section of this research approach will then seek to answer the question '*What if?*'. This will be undertaken by conducting a pilot implementation of the hypothesis and developed thesis concepts, in a real-life industrial situation. Evaluation and further testing of the pilot study results will be undertaken to justify the validity of the overall approach, Lewis-Beck [577]. An overview of the formulated research methodology can be viewed in Figure 3.1.

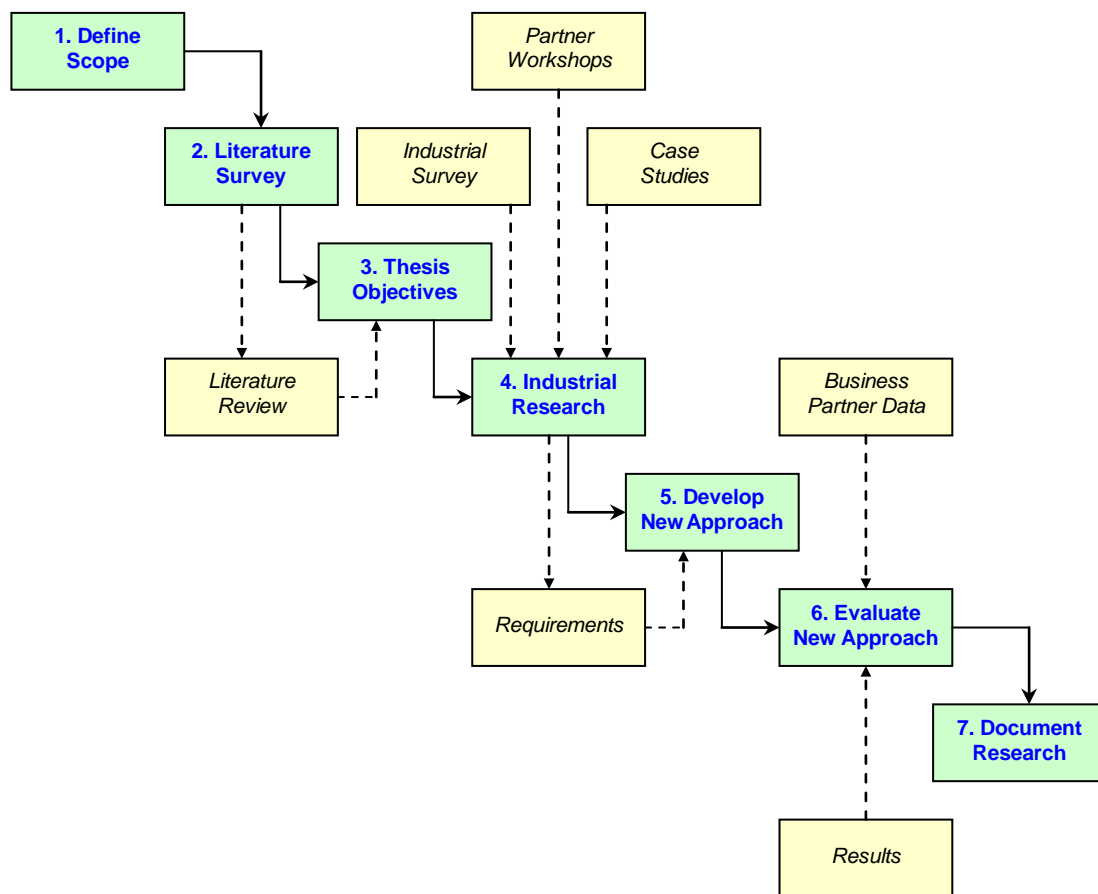


Figure 3.1: *Research Methodology, developed from Bickman and Rog [574].*

In essence the new approach will be based primarily around developing and applying the experimental concepts of process simplification, system decomposition and abstraction, with a view to enabling improved change capability. Based upon this foundation, a new typology of IT system for utilisation by SMEs is presented. This is essentially a reference model for 'Business Strategy Driven IT Systems'.

Initial research effort is aimed at gaining a fundamental understanding of related problems and solutions within the arena of manufacturing business systems and potential approaches to solution implementation. Having completed this initial study phase, general requirements of Business Strategy Driven IT Systems will then be formulated and the potential utility of these requirements verified, before being utilised as a foundation for the development of the IT Route Map. In the final study phase the applicability of the Business Strategy Driven IT Systems concept will be assessed through implementation and evaluation of the thesis concepts at the premises of a partner SME. Hence this programme of study essentially comprises the following research activities:

- ❑ **Literature Survey:** Study concentrated on analysing publications in four related areas, namely the contemporary business arena, management concepts, manufacturing philosophies and techniques (with special regard to MRP type solutions) and IT approaches.
- ❑ **Industrial Surveys and Case Studies:** Visits will be made to relevant companies and structured questionnaires submitted to ascertain the main problems and requirements associated with the implementation of MRP/MRP II/ERP type systems. This work is aimed at empirically confirming the primary notions and assumptions made when formulating this research study and assisting in the development of more detailed business requirements.
- ❑ **User Requirements Analysis, Modelling and Workshops:** Domain study and gap analysis research activity will be carried out to determine the major differences between typical AS-IS and potential TO-BE systems and processes used by partner SMEs. Seminars will also be held to help develop an exchange of ideas and later to detail semi-generic requirements of and solutions comprising the developed approach.
- ❑ **IT Route Map Creation:** Findings from the completed research will allow 'best practice for SMEs' to be identified and incorporated together with new business requirements into the IT Route Map. IT Route Map creation will be centred on the definition of a Business Model Template, a new Systems Architecture and an Implementation Framework using existing enterprise and software engineering tools.

- ❑ **Industrial Concept Evaluation:** This will be achieved by assessing results found when using the IT Route Map for a new systems implementation at a partner SME. Prior to the new implementation, critical success factors will be identified, against which the performance of the methodology can be measured and verified by the collaborating enterprise and research author.

3.7 Business Strategy Driven IT Systems

The literature describes the rise of a manufacturing enterprise in a networked world. But to people working in the SME business community these descriptions are difficult to utilise. Most businesses need to adopt IT. But IT systems have grown in complexity and cost and they lack a clear understanding of the concepts and issues that surround them. It is not clear what practical steps can be taken to cope with such phenomena. IT has pervaded many aspects of our lives. But it remains difficult and costly to sift through the hype and work out where value addition can be achieved to help cope with the confusion. This study proposes the use of, and will assess benefits arising from, 'Business Strategy Driven IT Systems'.

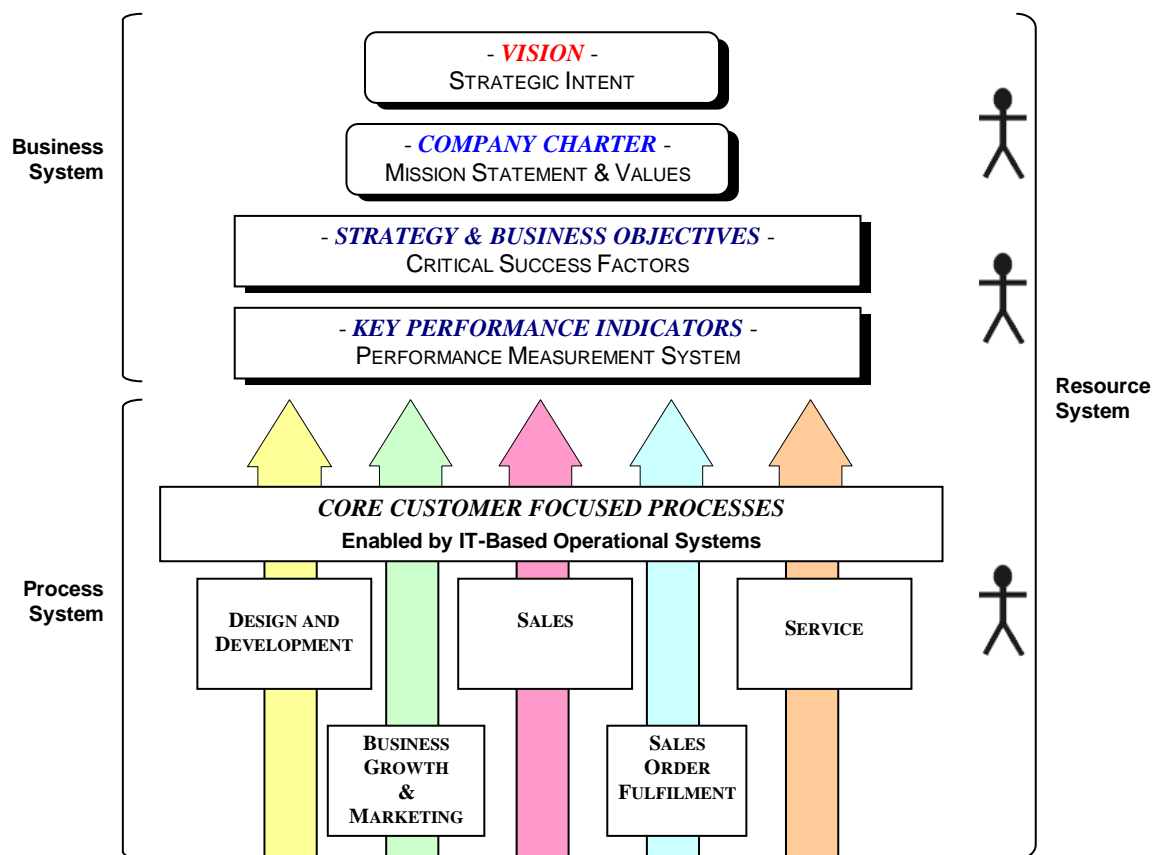


Figure 3.2: Aligning IT and Organisational Processes to Strategy

The approach proposed will provide a context within which specific businesses can exploit available IT systems with competitive advantage whilst recognising resource constraints. Key simplifying principles, which are tested by this thesis, are that (1) *any SME business is an entity which aims to transform inputs to outputs in order to increase their value and thereby realise profit for the entity and its stakeholders* and (2) *that IT is a primary mechanism for enabling (1)*. As such Business Strategy Driven IT System development can be viewed as encompassing analysis, specification, design and implementation, of manufacturing business systems where these activities reference a defined strategy of the enterprise. Figure 3.2 represents the author's preliminary vision of aligning IT and organizational processes to strategy within a manufacturing enterprise.

CHAPTER 4

EARLY INDUSTRIAL SURVEY

4.1 Introduction

The aim of this thesis chapter is to present survey work conducted upon the use of advanced business systems implementation, tools and techniques within contemporary SMEs. A survey strategy was chosen at this point of the research as it would assist the author in two main ways:

- 1) It would aid the author, as descriptive research, in attaining a good understanding of the current status or '*what is*' of advanced systems implementations within SME. Allison et al [573] and Bickman and Rog [574] support this general research concept.
- 2) It should lend quantitative support to the thesis' primary notion and assumptions, therefore combating the common argument that if only case study data was used in isolation, research work may lack precision and rigor, Yin [575].

Additionally, the survey would contribute to bridging an identified gap in current literature and research. Whilst several authors, including academics, practitioners and consultants, have conjectured about the applicability and deployment of MRP/MRP II/ERP type systems within large enterprises [9] [11] [12], few have provided empirical research on this subject or concentrated their focus upon SMEs [9] [15] [16]. It was anticipated that this early survey and the further case study work (reported in Chapter 5) would extend the researcher's insight into future enterprise requirements and as such would enable necessary precepts of a Business Strategy Driven IT Systems approach applicable for ETO/MTO SMEs to be identified.

4.2 Survey Methodology

After much consideration of existing research on strategies for undertaking surveys [578] [579] [580], it was decided that a 'simple' survey design was to be employed within this study section. This was chosen for a number of reasons. a) It is acknowledged by Robson [576] as an adequate tool when seeking to find information

about the incidence and distribution of particular characteristics, and of possible relationships between them. b) It would allow anonymity, which can encourage frankness [576]. c) It could later act as the formal 'pre-experimental' design of a larger research effort or be used as a 'regular' survey if the research was to continue, Allison et al [573]. d) It would be relatively quick (estimated at 12 weeks for 50 respondents) and easy to produce small-scale valid results, Lewis-Beck [577]. The time budget for designing, undertaking and analysing a large-scale survey of 1,000 interviews is considered by Robson [576] to be in excess of 34 weeks, and as such this was considered to be unrealistic and too long a period for this initial thesis work.

The potential disadvantages of this approach were considered to be. i) The survey may have a low response rate. ii) Ambiguities in, and misunderstandings of, the survey questions may not be detected and iii) Respondents may not treat the exercise seriously and you may not be able to detect this. It was anticipated that through explanation and close attention to questionnaire design the potential problems would have a low impact upon the work undertaken here.

The following steps in the design of the survey were utilised based upon recommendations provided by Hoinville and Jowell [581]:

- 1) Identify the general purpose and the specific information requirement:
 - a) Confirm preliminary research analysis has indicated that a survey(s) is the most appropriate way of addressing the research question(s)?
 - b) Clarify the research question(s)?
 - c) Develop a range of sub-questions, or subsidiary topics, relating to the central question.
 - d) Work out the specific information required in connection with each topic or sub-question.
- 2) Construct the questionnaire.
- 3) Determine the population and the sample to be selected.
- 4) Undertake the survey.
- 5) Provision of survey analysis and data interpretation.

The purpose of the survey was to provide generalised information pertinent to the deployment of MRP/MRP II/ERP implementation, tools and techniques within SMEs. As such the questionnaire entitled, 'Survey of SME Advanced Business Systems

Implementation, Tools and Techniques' (Appendix A) was developed and its scope limited to 5 main questions.

- 1) What is the background of the company?
- 2) What is the business environment that the company operates in?
- 3) What IT exists within the company and how is it deployed?
- 4) Which management tools and techniques does the company use?
- 5) What are the key issues faced by the company, in terms of implementing advanced business systems?

These were then transposed into the 5 questionnaire sections. Namely, General Background, Business Environment, IT Characteristics, Tools and Techniques and Key Issues Faced to provide simplicity of design. Rather than being definitively focussed on specific areas of research interest such as, IT resourcing or software flexibility, the survey was designed to gain general information that would provide the author with a broad understanding of the study environment. Specific information for each section was selected after research and trade literature had been filtered to identify systems, practices and techniques that are relatively well established.

The General Background and Business Environment contained questions relating to the activity, size, product range and market structure of the survey enterprise. From these two survey areas, it would prove easy to establish a high-level view of ETO/MTO characteristics and their activities. Section three of the survey, IT Characteristics, was designed to elicit a more detailed understanding of the management and utilisation of IT within SMEs and comprised questions such as, Whether the enterprise was aware of, used, or planned to use, various types of software? or What were the key factors when considering a new IT system?

The fourth section, entitled Tools and Techniques considered the wider application of management and IT implementation techniques. It consisted of more textual response questions because the overall subject was considered to be too large to try and represent it as simple selection questions. The aim of the section was to provide a general flavour of the types of approaches SMEs were utilising and to view if there existed evidence for commonality of approach between them. The final section, Key Issues Faced, incorporated questions pertaining to the MRP/MRP II/ERP system

deployment, success criteria and potential future directions. The final question of the survey, 'Please comment upon any further issues / limitations related to the utilisation of advanced business systems within your company?' was included and of open format to ascertain if there were any additional issues that were not previously covered in the survey design.

As the population of SMEs who had recently implemented an MRP/MRP II/ERP type of business system would be difficult to ascertain, on a large scale, a target sample of 35 was selected from SMEs with prior association with the University, the Teaching Company Directorate, or author. This was deemed to be a valid compromise between time-taken and the size and representativeness of the sample from which data would be collected. A cut off date of 6 weeks was set to ensure that results could be produced within a reasonably short time frame and that the respondents still maintained the explanation of the survey purpose in their minds when completing the questionnaire. It was anticipated that a response rate over 50% would be sufficient to draw valid conclusions from, as suggested by Robson [576] and this was considered to be fairly achievable due to good relationships that existed between the parties involved. All questionnaires were to be targeted at the senior enterprise management or the people with direct responsibility for IT systems used within the SME, so as to ensure that the widest potential ability to answer all of the questions effectively.

4.3 Survey Results Review

Of the 35 enterprises surveyed, 21 usable responses were received (60%) and comprise the survey findings. Responding enterprises collectively represented 11 different industry groups, with a high proportion (81%) serving predominately international markets. Within the study group, all enterprises employed less than 500 staff and over half (52%) had staff located in more than one site. Of the 11 geographically distributed enterprises, 3 had sites spread around the UK, whilst the remaining 8 had their operations sited around the world. Within the ten years prior to the survey 86% of the enterprises had been involved in one or more M&A activity.

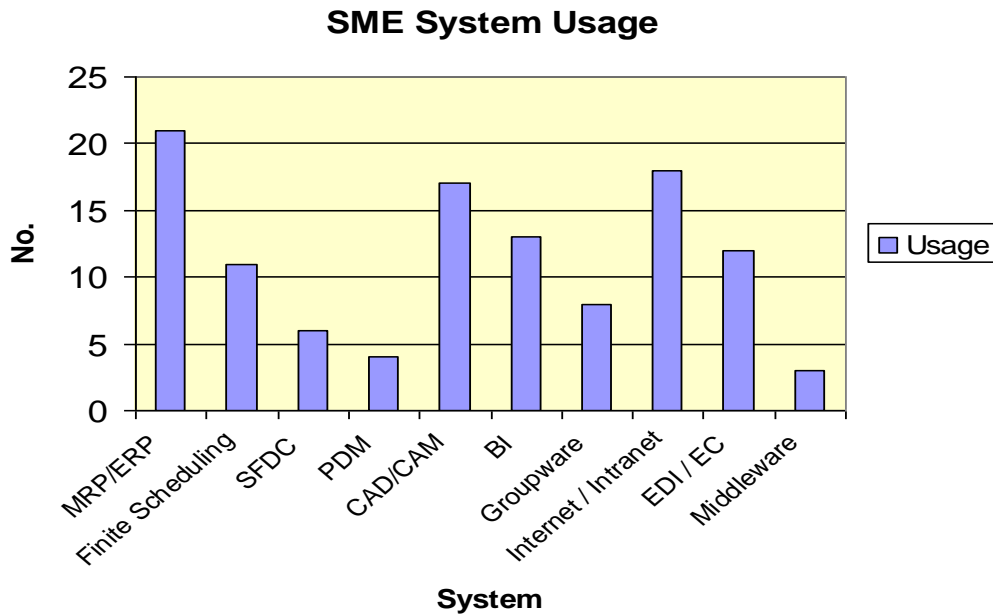


Figure 4.1: *SME Computer System Usage*

67% Of the enterprises surveyed did not have a separate IT department and 19% did not have a dedicated IT resource. Rather, in those companies management responsibility for the IT function generally resided with middle management, who had management responsibility for both strategy and day-to-day operation. When considered as a whole, on average the 21 responding SMEs deployed 32 PCs each, this figure equating to one for every 12 employees. All enterprise management engaged in responding SMEs had a high regard for the business benefits and competitive advantage that can accrue from using IT. Also in relation to overall system usage for the 21 responding enterprises, the profile shown in Figure 4.1 applied.

Although other IT systems, such as APS and Data Warehousing, were not yet used within surveyed SMEs, the responses indicated a positive attitude towards their future adoption. This is illustrated by Figure 4.2. All of the respondents who were not currently using Internet / Intranet technology had a desire so to do. Whilst all those considering the adoption of Data Warehousing and CRM felt that they would require Middleware to facilitate future system implementation. In relation to system awareness, a significant number of the SMEs had not heard of Workflow, Groupware, CRM or Middleware applications. More than half of the enterprises had moved from the combined use of paper based and ad-hoc computer systems to that of a so-called ‘advanced business system’. In such cases 90% of implementations required additional

programming outside that initially provided by the core advanced business application. System upgrades to the core package were typically required by responding SMEs every 1 to 2 years.

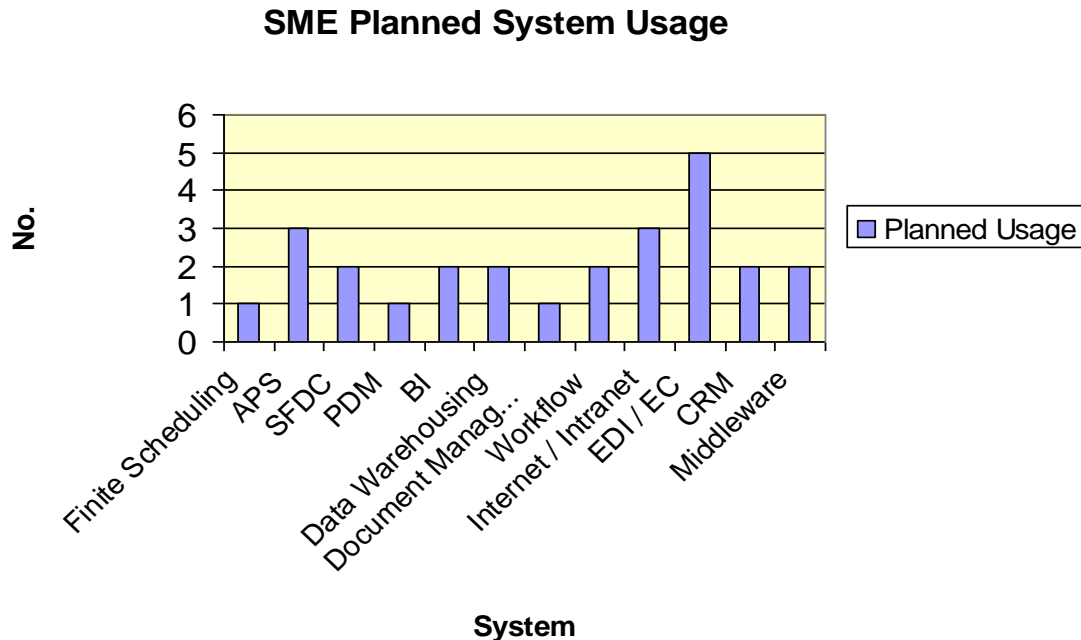


Figure 4.2: *SME Planned Computer System Usage*

The three main reasons stipulated for implementing advanced business systems were: 1) to facilitate business growth, 2) to achieve a reduction in production costs and 3) to facilitate business integration. 17 Out of 21 respondents admitted that they had undertaken no detailed cost / benefit analysis prior to implementation. 15 Stated that they had not sought any professional advice on the selection of software but relied heavily on the reputation of the vendor and its salesmen's performance. Only 9 employed business process analysis techniques to help them to deduce their system requirements.

All respondents agreed that resultant implementation of their systems had delivered business benefit and viewed the adopted use of such systems as a crucial step in maintaining successful operation of the enterprise. When answering follow-up questions, only 43% stated that they were happy with vendor performance, 38% used a recognised implementation methodology (provided by the vendor or implementation partner) and only 33%, were satisfied with the flexibility of the implemented software. Late IT system implementations were generally blamed upon a combination of

inadequate management commitment, changing business requirements and problems associated with matching system functionality to current enterprise operation.

15 Enterprises (71%) stated that they would implement an advanced business system again, with the remaining stating that they preferred the bespoke route. An issue of total cost was a prime consideration driving this decision. It was felt by the majority (76%) of enterprises, that they probably had an inadequate IT capability to effectively select and implement such systems. Finally, when answering the crucial question of whether they thought they could actually meet, the true financial cost of the system (both monetary and in terms of business disruption), only 57% said that they could. Further results can be viewed in Figure 4.3.

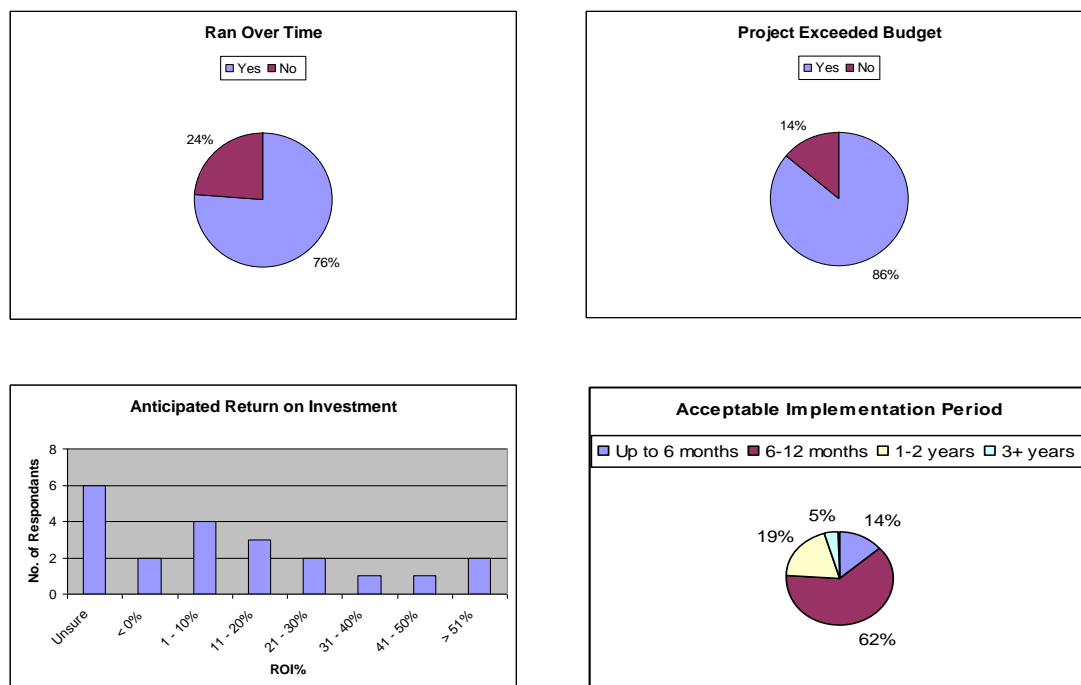


Figure 4.3: *Selected Survey Results*

4.4 Methodology Analysis

The brief survey presented here provides a useful introduction into some of the problems and issues connected with system functionality, deployment methodologies and financial justification of MRP/MRP II/ERP business systems within SMEs. Despite the fact that the survey only covered a relatively small sample size, it has aided the author in further developing his knowledge and preparing additional justification and support for his overall research effort.

From the survey results, commonality of findings was seen with those of Armstrong and Coyle [15] who suggest that “SMEs have the desire to implement manufacturing business systems but, do not necessarily have the skills and in-house expertise to undertake such projects”. Coherence was also observed with respect to work of Chamberlain and Thomas [487] who state that the primary reasons for implementing IT systems are business related and not technological. Furthermore Aglen [493] supports the new observation made that an approximate 3:1 split between package and bespoke system usage is not uncommon. Whilst all participant study enterprises agreed to the importance of the Internet, it was observed that the awareness of other complementary systems and techniques will typically be more advanced in larger enterprises that possess dedicated IT departments and staff. None of the enterprises surveyed admitted that any of their IT projects had ended in failure. However in support of Stewart's [491] assertion that “between one quarter and one half of implementations fail”, the case study findings showed that three quarters of survey projects were late and over budget. Overwhelmingly, the primary concerns voiced by the SMEs studied were related to software flexibility, implementation time and cost. Weston [471] supports this notion and suggests that manufacturing business systems should be change capable. Durumusoglu et al [494] emphasise that a realistic time-period in which to complete a manufacturing business system is around 12 months, and Armstrong and Coyle [15] advise that ERP solutions need to be made available to SMEs at relatively low cost.

One of the most worrying aspects related to SME deployment of manufacturing business systems was found to be a lack of detailed requirements analysis prior to system acquisition. It is not reasonable that an SME should blame vendors for functionality problems if IT purchase is made on vendor reputation, salesmen and sketchy requirements definition alone.

In summary, the results of this survey support the notion that MRP/MRP II/ERP and associated complementary systems are now routinely used by a wide range of SMEs, and are producing significant, affordable, benefits. The main problems identified relate to, the overall cost, expanded time scales and lack of flexibility (as sufficient change capability is not an inherent property of the contemporary packaged software).

CHAPTER 5

INDUSTRIAL STUDY WORK

5.1 Introduction

The aim of this chapter is to build upon the initial survey findings presented in Chapter 4 and offer a more detailed investigation of the MRP/MRP II/ERP requirements and implementation problems, through the completion of three industrial case studies. It was anticipated that by acquiring knowledge through direct experience the author would be better able to develop a solution more closely aligned to actual business requirements rather than being based upon theoretical and academic concepts alone.

The author was fortunate (through his employment as a project engineer and subsequently as a TCA and a business analyst) in being able to gain access to over 15 SMEs, who were in the process of implementing various different types of manufacturing business systems. These comprised, both independent enterprises and ones that formed constituent parts of larger organisations. In general, implementation of these manufacturing business systems was a response to challenges to their growth and competitive position. Three enterprises were chosen for detailed study, namely: Morris Mechanical Handling's Industrial Cranes Division (ICD), Tritex International Ltd, and Courtaulds Textiles' Lingerie and Hosiery (L&H) Division. All three of these enterprises employ ETO and MTO production strategies, and are made up of many subsidiary companies, but together they represent three distinct industrial sectors, Table 5.1.

No.	Case Study Enterprise	Line of Business	Author's Role	Study Period
A	Morris Mechanical Handling Ltd. (Industrial Cranes Division)	Design and manufacture of industrial cranes and materials handling equipment.	Project Engineer	Apr - Oct 1995
B	Tritex International Ltd.	Design and manufacture of specialist circular knitting machines.	Teaching Company Associate	Dec 1995 - Nov 1997
C	Courtaulds Textiles Ltd. (Lingerie and Hosiery Division)	Design and manufacture of lingerie and hosiery.	Business Analyst	Dec 1997 - Dec 1999

Table 5.1: *Case Study Overview*

It was realised that a detailed study of each enterprise would offer a distinctive, but valuable opportunity to contribute specific knowledge to the research aims of the

thesis, due to their differing sizes and scope. An initial overview of the three case study enterprises can be viewed in Table 5.2.

Summary	Feature	Case A Enterprise	Case B Enterprise	Case C Enterprise
Overview	Case Study Purpose	Globalisation achievement techniques	MRPII life-cycle and resource constraints within SMEs	M&A activities. ERP and complementary systems implementation.
	Period	Project based over 6 months. Global systems design and development	Project based over 2 years. MRPII package implementation	Multiple projects over 2 years. ERP, BI, EDI and APS implementation
Enterprise Strategy	Business	Production of industrial cranes	Production of specialist circular knitting machines	Production of lingerie and hosiery
	Strategy Employed	Differentiation	Differentiation	Differentiation Focus
	Purpose	To produce high quality cost effective cranes	To produce knitting machines to specific customer requirements	To become a major international lingerie and hosiery business
	Goals / Measures	Market leadership	Business growth	Increased market share
Structure	Ownership	Part of a larger US parent enterprise	Private	Part of a larger UK parent enterprise
	Turnover	£7 million	£2 million	£333 million
	Employee No.	53	50	4500 (In total)
	Business Units	1	5	10 (50 sites)
	Organisation	UK and South Africa	UK and USA	Global, Distributed
	Culture	Team	Team	Power
	Orientation	Product focus	Product focus	Quality
	Management Structure	Flat	Flat	Hierarchical
Customers Focus	Products	ETO/MTO workshop cranes and kits	ETO/MTO circular knitting machines	ETO/MTO Hosiery and Lingerie
	Volume	Low	Low	Medium
	Variety	Medium / High	High	Medium / High
	Process	Discrete	Discrete	Batch
	Services	Design, installation, service, spares, warranty and training	Design, installation, service, spares, warranty and training	Design, warehousing and distribution
	Markets	Global	Global	Global
	Market Characteristics	Fit for purpose / functionality / reputation / safety	Fit for purpose / functionality / reputation	Quality / cost / delivery performance / responsiveness
	Market Support	Agents / manufacturing subsidiaries / joint ventures	Agents / acquisition	Manufacturing subsidiaries / joint ventures / acquisition
	Role of Manufacturing	1. To maximise profits through increased efficiency 2. To maintain market leadership through strategic development of facilities	1. To maximise profits through increased efficiency 2. To maintain market leadership through strategic development of facilities and increase manufacturing flexibility	1. To delivery high quality products on-time 2. To facilitate significant cost reduction through the development of offshore manufacturing facilities

Table 5.2: Case Study Enterprise Summary

In essence, the case studies represent a diversity from which the author would be able to view the progression of enterprises, as they grow in size and to gain understanding of the opportunities available to them at each stage of development. From the smallest enterprise, Tritex represents a small family run business (< 100 employees), comprised

of five complementary business units, offering specialist circular knitting machine design, manufacture and support services. Recently, the enterprise had installed a contemporary MRPII system, but had struggled with its deployment due to lack of knowledge, experience and problems with matching business requirements to in-built system functionality. In particular, the case study would be useful to provide the author with awareness of the issues facing enterprises that are exposed to restrictive resource constraints.

Whilst, the ICD of Morris was not that much bigger than Tritex in size (53 rather than 50) and turnover (£7M as opposed to £2M), it was however part of the larger organisation, Morris Mechanical Handling Ltd (approximately 500 employees), and had a fundamentally different product range. These comprised large ETO and MTO electric overhead cranes rather than smaller scale, complex circular knitting machines. The Division had recently, implemented a basic ERP system internal to the local site, but it now required insight into achieving and supporting globalisation. Specifically, the Division wished to provide IT support for overseas sales agents and manufacturing subsidiaries, but did not know how to and what risks would be inherent in any decisions it made.

The L&H Division of Courtaulds was to be studied, as it was comprised of several diverse business units, manufactured textile products, and would provide visibility of what can be achieved by being part of a much larger global enterprise. Additionally, as Courtaulds had recently undertaken the purchase of a competitor firm, this would furnish the author with improved understanding of M&A processes. The L&H Division was a mature user of IT and ERP systems, deploying a heavily modified but, internally packaged ERP solution to its subsidiary business units. The main problem that the L&H Division was facing mainly related to business and system integration, both with customers and existing subsidiaries that had not yet adopted the corporate IT solution. Additionally, it was confronted by ERP system support issues and facilitating the relocation of previously UK-based manufacturing to offshore locations.

5.2 Investigative Approach

Overall, the case study research method proposed by Yin [577], comprising three stages: 1) Define and Design; 2) Prepare, Collect and Analyse; and 3) Analyse and

Conclude, was adopted. This was chosen as it is recognised by many as a defacto standard within this field [574] [576]. At this stage of study no attempt was made to formalise the data capture or to use supporting modelling tools as a reasonable balance had to be maintained between employment priorities and more personal academic research interests. However for all three case studies the approach focused on:

1. Elicitation of background information about the Enterprise, its products and markets.
2. Analysis about the Strategic Interest of the Enterprise.
3. Development of an IT system and operational overview
4. High level review of IT-related business concerns.

Knowledge elicitation activity under phase one was carried out via a consideration of the history of the enterprise, its current structure and properties of its markets. In the second phase, strategic analysis was undertaken. This was achieved by holding high-level interviews and brainstorming sessions with senior members of staff to develop coherent understandings about their various concerns related to the overall strategic direction of the enterprise. The IT system and operational overview knowledge acquisition work comprised two distinctive parts. The first IT strategy related part was conducted in a similar way to that used in phase two to conduct strategy analysis. The second was centred on a consideration of how IT systems might be used to support the operation of the business as a whole. The final phase of the approach deployed to acquire case study knowledge concerned a review of IT-related business issues and sought to identify problem aspects of manufacturing business system design and implementation within the enterprise. Essentially this last phase of knowledge elicitation centred on a gap analysis to contrast and compare the ‘AS-IS’ and possible ‘TO-BE’ IT system scenarios.

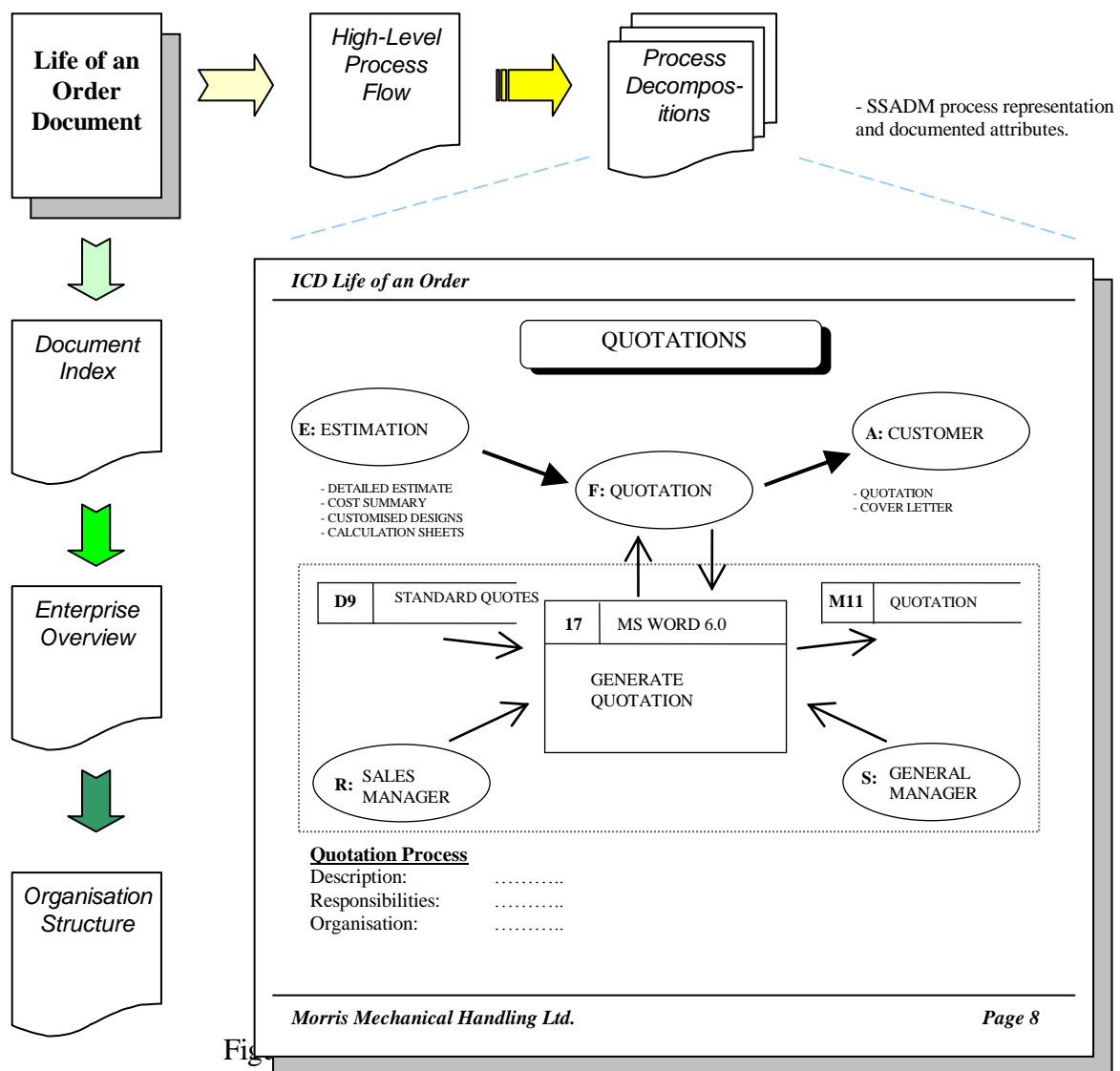
All stages of the approach required an initial consideration of how robust (case study) data might be collected and used. In this respect the use of several data capture and representation methods was considered. Candidates here included IDEF [207] and GRAI [211]. However the author chose to utilise the Structured Systems Analysis and Design Methodology (SSADM) [582] [583] as it is recognised by the CCTA as a defacto standard, because of his previous familiarity with using the tool for SME

clients and the ease with which high-level process and system flows could be pictorially represented; so that results can be communicated to relevant personnel. In this early case study work it was envisaged that the process of understanding IT systems operation (within each enterprise) was expected to follow a process of tracing a customer order thorough the entire business cycle and documenting aspects of the processes and systems involved at each stage. Here it was decided to generate a document entitled 'Life of an Order' (an approach initially directed by P&H Harnischfeger, the parent of Morris Mechanical Handling Ltd) which encoded a sufficiently comprehensive view of IT systems used in each case study enterprise. These documents would contain an introduction to the enterprise, an overview of the organisational structure, a high-level process summary and then individual SSADM-based process decompositions and associated process attributes, such as process responsibilities and organisation. Figure 5.1 shows the overall 'Life of an Order' document structure and an example process diagram for the quotation process undertaken within Morris Mechanical Handling Ltd.

As anticipated it was found that the 'richness' of the knowledge elicited was dependent on the knowledge and capabilities available to the people interviewed and the number of people interviewed with unique concerns. However a series of issues were raised when seeking to interview high and mid-level management as well as shop floor personnel. The series of issues raised included:

- ◆ Few employees hold a complete view of the enterprise.
- ◆ Time constraints can restrict the analyst to summary level analysis and as such may lead to invalid assumptions.
- ◆ The employee may not know exactly how he solves a problem, he may say 'Well its obvious'.
- ◆ The employee may use loose terms such as 'very' or 'often' when a more precise measurement is needed.
- ◆ The employee and the systems analyst may have different conceptualisations of the domain.
- ◆ The employee and the systems analyst may use jargon, which the other does not really understand.
- ◆ Information about specific aspects of enterprise strategy, product development or process operation may be classed as confidential.

Importantly, the knowledge elicited also required validation by all participants to ensure that an accurate picture, of various fragments of a bigger picture, was obtained. This was undertaken through teach-back exercises and by testing processes and system actions upon replica copies of the live-system environment. Appendix B describes the three case studies and the knowledge acquired by following the knowledge elicitation approach described above.



Fig

5.3 Case Study Results

Whilst similarities in their overall business operation could be seen, the three study enterprises exhibited varying classes of IT system and level of resource, Table 5.3. All enterprises operated within global markets and had recently been involved in M&A activity. P&H Harnischfeger had recently acquired Morris, Courtaulds had purchased Claremont Garments in 1997 and Tritex, within the period of investigation, had placed consideration upon the acquisition of Cobra Machinery Ltd. In terms of stages for achieving globalisation, provided by Lasserre [42], Courtaulds could be seen as the most advanced, utilising overseas manufacturing subsidiaries as well as joint ventures. Both Morris and Tritex, due to lack of experience and financial resources had primarily concentrated upon sales agent development.

Summary	Feature	Case A Enterprise	Case B Enterprise	Case C Enterprise
Strategy	Management	Direct to Finance	Production Director	Direct to Finance
	Objective	Business growth platform, improved contract control and overhead reduction	Business growth platform and improved contract control	Stable, low-risk solution targeted at achieving customer goals and continual cost reduction
	Formal Planning	Yes	No	Yes
	Service Levels	No	No	Yes
	Budgetary Control	Yes	No	Yes
	IT Perception	Good	Good	Good
	Planned Availability	9-5 Mon-Sat	9-5 Mon-Sat	Moving towards 24/7
Organisation	Sites No.	1	1	50
	IT Employee No.	4	0	45
	User No.	80	14	400
	Co-ordination	Central	Central	Central and Local
IT	Platforms	IBM Unix, Novell	SCO Unix	IBM AS400, AIX & Solaris Unix, Microsoft NT, Novell
	Business Systems	Baan Triton (ERP)	Exel Efacs (MRPII)	Primarily SSA BPCS (ERP)
	Accounting	Triton	Sage Small Business	QSP Olas
	Helpdesk	Yes	No	Yes
	E-mail/ Workflow	No	No	Lotus E-mail
	Office Applications	Microsoft Office	Microsoft Office	Microsoft Office
	Reporting Tools	Triton 4GL Tools	Informix SQL	AS400 Query / Cognos BI
	Networking	LAN	LAN	LAN / WAN / VPN
	Internet / EC	No	No	EDI / Corporate Web site
	Development	External	External	External

Table 5.3: *Case Studies: IT Overview.*

All the enterprises selected product specification, customer service, flexibility and quality, not necessarily pure cost, as the key order winning factors from the list defined by Kruse [285]. Despite Courtaulds being comprised of multiple business units, larger employee numbers and greater product volumes than Morris or Tritex, a distinct

market shift to smaller batch sizes with a higher degree of product personalisation was being made. Customers, for some ranges of women's underwear, could now place orders through a selection of common high street stores for small volumes of specific garments or even individually tailored products. The primary differences between Courtaulds and the other two enterprises were identified as its greater focus upon production cost and its ability to raise investment capital from its parent. Tritex, in particular was regularly exposed to demand variability and cash flow problems.

In relation to IT characteristics, all had recently implemented or were in the process of implementing MRPII and ERP type systems. Whilst Courtaulds and Morris had in employ experienced and dedicated IT professionals, Tritex had enlisted the assistance of external consultants and had embarked upon government schemes, i.e. TCS. Despite the wealth of knowledge contained with these personnel and schemes, all three case study enterprises were found to experience real problems in achieving a high degree of fit between MTO and ETO business operation and standard ERP system functionality.

Summary	Problems and Concerns	Case A Enterprise	Case B Enterprise	Case C Enterprise
Business	Potential loss of competitive advantage from the forced utilisation of generic processes	5		5
	High cost of ERP systems deployment	5	5	5
	Long systems implementation time	5	5	5
	Degree of ERP system fit to enterprise processes	5	5	5
	Personnel numbers required to operate system	5	5	
	Access to skilled IT professionals at low cost	5	5	5
	Accurate and timely product costing information	5	5	5
	Effective training and product support	5	5	
Technical	Hardware and software upgrade requirements		5	5
	Management and support of system modifications		5	5
	System performance problems		5	5
	System availability			5
	Latency (timeliness) of system information	5		5
	Systems integration problems	5	5	5
	Enforced customer requirements and standards			5
	Item proliferation and data archiving		5	5
	Reliability of batch processes		5	5
	Lack of integral data reporting	5	5	5
	Remote access and networking	5	5	5

Table 5.4: *Case Studies: Business and IT Concerns.*

Tritex largely remained dependent on its core ERP system functions and had been forced to make the best use of the system as it stood. Morris chose to construct a largely separate and standalone bespoke software package to realise its customer quotation process and Courtaulds had in effect constructed its own version of an ERP system by implementing a number of additional sub-systems and modifications that link to its core BPCS package. All serve to show how the impact of ERP system rigidity and enterprise financial constraints can limit the extent to which a packaged ERP system can effectively be developed to underpin SME needs. Table 5.4 presents an analysis of the case study group's business and technical concerns, in relation to the deployment of manufacturing business systems.

5.4 Survey Conclusions

In summary, the case study work undertaken in this chapter has provided a valuable insight into the deployment of MBS with manufacturing enterprises. It also provides specific results that are consistent with findings from the survey research undertaken in Chapter 4. Therefore in later thesis chapters the initial case study findings are used as a foundation to develop an IT Route Map and to test primary notions of this thesis. Key SME concerns observed in respect to the three case studies were as follows:

- ◆ Increasingly needs arising in current business environments are outpacing available IT systems development capabilities.
- ◆ Access to skilled IT professionals is problematic.
- ◆ ERP system operation is typically based upon the notion that employees have full-time job roles implicitly defined in the system. SMEs typically deploy a minimum number of IT support staff who may also undertake other business and/or operational roles.
- ◆ Standard ERP systems do not in general achieve a close functionality fit with specific ETO and MTO enterprise needs
- ◆ Additional IT sub-systems are required to provide functionality that is not present (or adequately provided for) in standard ERP systems. Achieving integration between additional IT applications and ERP systems generally requires bespoke interfaces (sometimes called adapters) to be constructed, even though some ERP systems offer interfaces that are standardised to some extent.

- ◆ Effective links between different ERP systems are difficult to achieve. In cases where an enterprise consists of multiple business units (or are involved in M&A activity) many different computer systems may require integration.
- ◆ System upgrades are typically frequent, expensive and generally do not deliver additional business benefit. Upgrading at regular intervals is a necessity though to maintain vendor supplied system support.
- ◆ Product quotation in terms of design and costing is commonly an integral part of any ETO or MTO environment and is poorly catered for by typical ERP systems. ERP Product Configurator system modules were found in case study work to be insufficiently sophisticated to deal with real-life situations, particularly where a large amount of new design work is required.
- ◆ MRP, even if run daily or with backflushing, does not offer suitable and timely information to enable ETO and MTO enterprises to operate at their fullest capability. Detailed process plans may not be known at the start of computer planning cycles. This may lead to insufficient account being taken of load implications when accepting a new order. Availability of simulation techniques from which manufacturing sites can make and deliver products most cost effectively is generally supported by APS systems but not by ERP.
- ◆ In the case study work ERP was not seen to adequately support an integration of customer, supplier and inter-enterprise business unit throughout the entire supply chain. Instead it was found to be common to facilitate 'fast-track' processes for regular supply-chain business transactions. Whereas standard processes have to be undertaken that are very time-consuming to undertake. For example Inter-company stock transfers may have to undergo full purchase order-receipt-invoice payment cycles rather than being the subject of one or two simple computer based transactions
- ◆ Customer and supplier pressures to integrate systems through the supply chain were common in the case studies. Larger enterprises typically have the upper hand and force low-tier suppliers to conform to defined standards or to use common software.
- ◆ Reporting functionality available within ERP systems is generally limited and constitutes simple queries and list style reports. Whilst efforts to provide improved report generators were found to be common, they do not generally come close to achieving the level of functionality that is delivered by many 'best-of-breed' EIS solutions.
- ◆ In respect of standard ERP, there was found to exist the assumption that enterprises will continually build upon the information contained within ERP databases and that the database tables will continue to grow. Although, such an eventuality might be preferred from an historical reporting basis, as item and transaction records proliferate through time,

the outcome was found to be considerable degradation of system performance. Effective methods of archiving data are not generally supported by contemporary ERP systems.

- ◆ ERP systems operate in a batch processing mode for multiple business operations (reporting, barcode transactions, EDI, etc) some of which require exclusive locks to be placed in several key data areas (MPS, MRP, backups, financial period closure/posting, etc). In the case study work this was found to require IT resource intensive operations that further constrain system availability.
- ◆ The cost of appropriate hardware and networking to provide effective global systems access (world-wide VPN) and operation (24/7) was reported by case study companies to be prohibitive for most independent SMEs.
- ◆ The time taken to chose and implement ERP systems effectively was found to regularly involve a 2-year period, whereas the results showed that a 12-month period is a more appropriate time-scale.

In addition to forming a basis for the IT Route Map development work of this PhD study, the thesis literature review and SME case study conclusions drawn here offer one possible starting point from which to improve the specification of general requirements for next-generation ERP systems. This research together with work experiences of the author at the case study enterprises has led to the construction and publication of four conference based research papers. The papers are included into Appendix C and provide useful findings on topics ranging from systems development for global manufacturing to implementing BPR and Intranet support within SMEs.

CHAPTER 6

THE REQUIREMENTS FOR A NEW APPROACH

6.1 Introduction

The purpose of this chapter is to propose common characteristics of SMEs, that operate ETO or MTO strategies, and to describe their unrestricted[♦] business system and technical requirements, based upon the previous literature review, industrial survey, case studies and findings from industry workshops. The intention is that the information provided here will alleviate any bias towards existing management and IT methodologies, thereby (1) effectively breaking free from the restrictive bounds of current thinking and (2) providing a viable foundation upon which an effective solution can be developed. In total four industry workshops were held at the University and were typically composed of middle management and IT employees from the partner SMEs, namely Morris Mechanical Handling Ltd, Tritex International Ltd and Courtaulds Textiles Ltd. Whilst the work undertaken in the workshops covered much ground and provided the opportunity for group interaction, each workshop had a defined purpose and a desired result to achieve, Table 6.1.

No.	Purpose	Format	Results
1	Strategic Analysis of Partner SMEs	Individual and group use of PEST, SWOT and Porter's Five Forces analysis to elicit strategic orientation of ETO/MTO SMEs.	Summary of common industry strategies and characteristics (Tables 6.2, 6.3).
2	Review of Current (AS-IS) Business Processes	Structured review of the SSADM based 'Life of an Order' models developed within the industrial case studies in Chapter 5.	Definition of industrial domain and core business processes (Figure 6.1).
3	Design of Semi-Generic (TO-BE) Business Processes	Detailed design and validation of new business processes using the process template defined in Chapter 8.	Business process model document for ETO and MTO SMEs (Appendix D)
4	User Requirements Analysis	Structured interviews and brainstorming of new business and technical requirements.	Summary of requirements (Tables 6.4, 6.5)

Table 6.1: *Industrial Workshop Purpose and Results.*

[♦] Unrestricted refers to conceptual thinking that is not constrained by contemporary technical limitations.

The common SME characteristics identified and developed in conjunction with the research collaborators led to agreement that for some strategic planning decision making ETO and MTO enterprise strategies can be grouped together and represented by a fairly abstract 'model' of a 'mass customisation' parent strategy. This was perceived to be the case because of similarities between their characteristics, adjacent position on the manufacturing continuum, and the common desire of customers to receive individually tailored products. Additionally, it was concluded that few of today's enterprises only operate one of the strategies, as this can restrict their ability to meet customer requirements and impact upon their position of competitive advantage.

Through workshop discussions, requirements of new approaches were considered, classified and validated by the research partners into three distinct groups: business requirements, technological requirements and general assumptions. These findings exemplified the potential importance of new approaches that can facilitate the detailed design of next-generation ERP systems, together with their rapid implementation and on-going development. The findings presented here also emphasise the need for public domain enterprise engineering concepts, which systemise considerations about resource constraints and their impact on business and technical concerns.

6.2 ETO / MTO SME Characteristics

Primary business activities in ETO and MTO are centred on the design, development and manufacture of individual products. Via these activities products are customised to meet specific customer needs and desires. As explained earlier, designated SMEs have less than 500 employees [20] but increasingly commonly need to operate within mature global markets that may have over-capacity problems.

Primary business problems are associated with inadequate growth of market demand, complex business management issues, inability to raise finance, inappropriate skill base and inability to implement new technology in a timely and cost effective manner [13] [20] [70]. An overview of common characteristic properties of the ETO / MTO SME domain is provided in Figure 6.1.

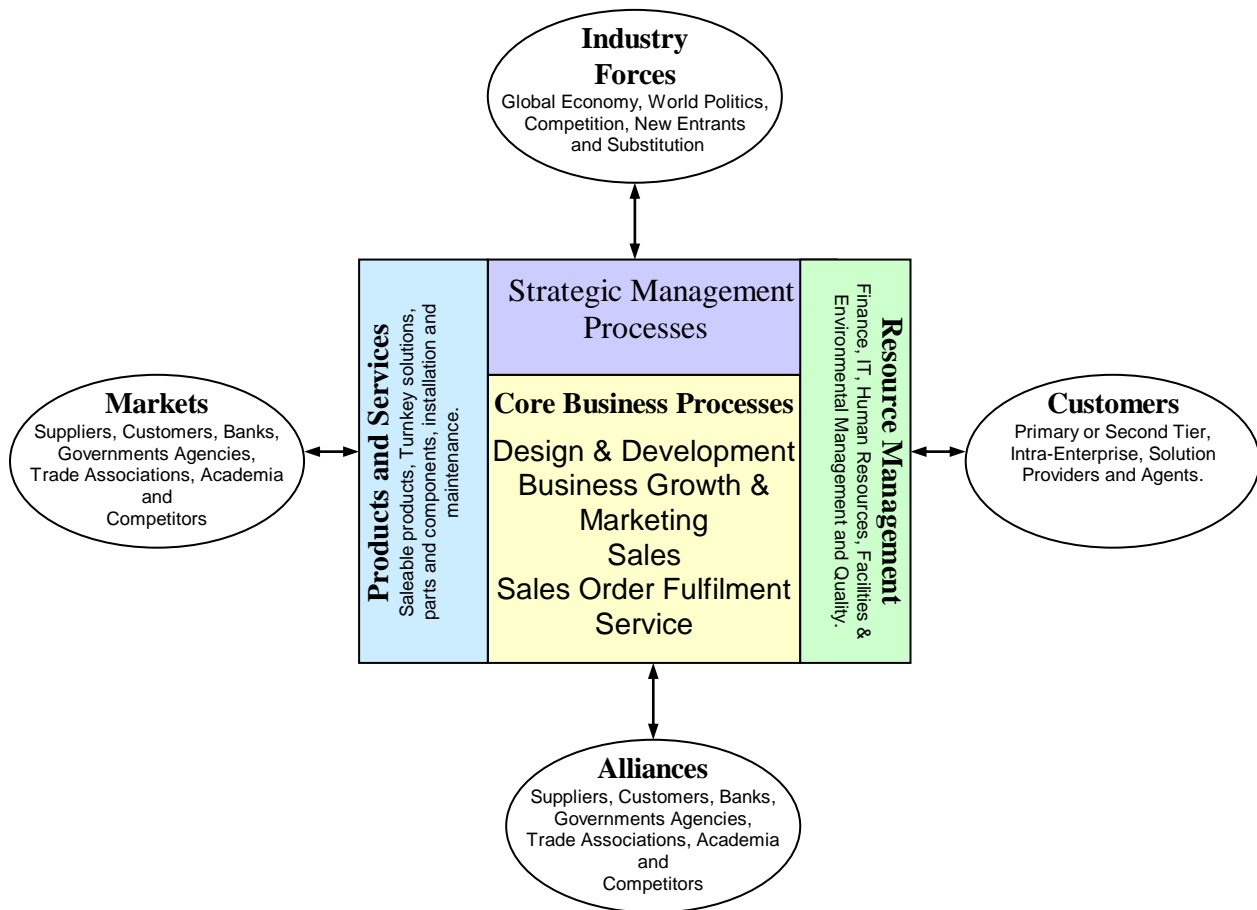


Figure 6.1: *Common Characteristic Properties of the ETO / MTO Enterprise Domain.*

ETO and MTO SMEs regularly look to government, local business support groups, trade organisations and academia to enhance business performance. The attainment of standards such as ISO9000 and Investors in People are considered to be valuable additions to the marketability of such an enterprise whilst at the same time can help deliver improvements in customer service and personnel [113]. Access to global markets is predominately undertaken through agency arrangements. However there is a willingness to consider other methodologies, such as partnerships or the creation of subsidiaries. Success in such ventures, in the large depends upon whether the enterprise can acquire appropriate knowledge and if the venture can be undertaken at acceptable cost [4]. Potentially ETO and MTO SMEs may regularly be a focus of M&A activity.

Primary order winning factors influencing ETO and MTO SMEs are: fitness for purpose, price, lead-time, and delivery performance. Financial penalties may be stipulated in purchase contracts, in the case of late delivery of goods or if goods do not

perform to an agreed capacity or level. Customer order acceptance is typically coupled to the availability of critical materials and capacity [395]. Enterprise strategies are normally based upon differentiation, but with a focus on lowering costs. Common functional strategies adopted by ETO/MTO SMEs are listed in Table 6.2.

Functional Area	Strategy Description
Marketing	Emphasise differentiated distribution, advertisement and promotion upon a broad scale. If possible at low cost.
Research and Development	Promote product and service R&D as well as process R&D.
Purchasing	Undertake the purchase of high-quality raw materials and components (inputs) at lowest possible cost. Conduct efficient, inventory and warehouse control. Establish close monitoring of supplier performance.
Manufacturing	Emphasise quality in operations, high throughput and delivery performance.
Human Resources	Implementation of a reward system that encourages output improvements or innovation, as well as reductions in cost.
Finance	Practice tight fiscal control, obtaining resources and funding business improvements, if possible, at low cost.
IT	Emphasise timely support and the delivery of pertinent information on costs of operations or innovation processes that are meant to yield differentiated outputs.

Table 6.2: Functional Strategies for Pursuing Differentiation.

Product volume and diversity can be mixed. Manufactured items such as cranes or specialised knitting machines may be required in very low or single unit volumes, whereas others such as clothing can be required in medium to large quantities. Particular items may be completely designed for the customer or based upon standard designs but with additional features. The demand for these products can also be highly variable with each manufactured product representing a large proportion of the enterprise's design and manufacture capacity [585]. Typically, customers either make single purchases or seek to establish much longer relationships with the enterprises concerned. This is especially widespread where the source of the product is limited to a few select enterprises. In such cases enterprises are focussing upon customer retention and the extensive use of marketing or M&A activity to achieve growth. Additionally, it can be observed that service and spare part businesses may evolve for these types of

enterprise, to support the major product groups and provide a stabilising income in periods of low demand.

Manufactured products in this domain generally have complex and multi-levelled component structures. This can give rise to several independent assembly stages that need to be co-ordinated with material and component supply. There may be little scope for widespread common components. High levels of uncertainty in terms of specification, costing and production planning distinguish patterns of product supply. Inaccuracies in initial product specification and configuration of the product add to rework levels in design and manufacture, consequently challenging the attainability of the delivery date and the desired level of profit. Furthermore, as a consequence changing business requirements and extended manufacture times, customers may request design alterations whilst the product is still being manufactured, Little et [396].

An effective cost accounting methodology can be seen to be an essential element of the enterprise's management system, Storey [586]. This is required to accurately estimate quotation costs and enable the correct allocation of expenses, as well as to provide a firm foundation for cost reduction programmes. Current systems for measuring resource utilisation and production output tend to be based upon the attainment of standard hours. This is especially the case where there is considerable labour content. Inventory is often directly related to distinct customer orders rather than being driven by lot sizing or re-order point methods. Although, the general philosophy is 'do not make it until you sell it', enterprises sometimes hold additional inventory for standard assemblies and to cover key replacement items for customers, but this can often become obsolete, Thomas [587].

Effective production planning is difficult to achieve due to the dynamic nature of the environment in terms of available resources, together with the level and mix of work, Federgruen and Katalan [588]. The unique nature of products can mean that the majority of the data pertaining to lead-times and operational processes are based upon estimates. Historical information may also be unreliable because of a tendency towards small batch sizes and the fact that components may have the capacity to be manufactured upon many different work-centres. Consequently, variances between planned and actual production may arise. This problem may be further exacerbated when BOMs are produced by the design function and as such may not necessarily

address manufacturing and assembly considerations. Additionally, design, assembly and subcontract operations planning are considered to be important activities as each can take the same (or more) time than the main component manufacture [396]. Physical factory layout, in the smaller enterprises tends to be organised into job shops rather than manufacturing cells. But a cellular approach is regarded by nearly all SMEs as the most effective method of shop floor organisation [56]. Key business processes for ETO/MTO enterprises, were concluded by the research partners to be as follows: design and development business processes, business growth processes and marketing, sales, sales order fulfilment and service business processes.

Business Arena	Manufacturing Environment
Enterprises < 500 Employees Global Marketplace Mature Markets with Over Capacity Problems Highly Variable Product Demand High Incidence of Mergers and Acquisitions Substantial Barriers to Growth: Finance, Skill, Technology & Business Process Orientation Multi-Site	High Production Complexity, Material and Capacity Driven Low Forecast Stability Design and Assembly Planning Required Direct Issue Components, Few Common Items High Labour Content, Work Centre Based Standard Hours and Operation Efficiency Customers Involved in the Manufacture Cycle
Products and Services	Methodologies and Systems
Product Attributes: Fitness for Purpose, Price, Lead-time and Delivery Performance Individual, High Variety Products Difficult Design, Costing and Product Specification Spares and Service Support Businesses Forging of Long-term Customer Partnerships	Government Agency and Academia Support ISO9000 / 14000 and Investors in People Use of Sales Agents to Trade Overseas Uneasiness with IT in General Reliance on External Assistance for IT Use of ERP to Support Growth, Reduce Costs and Facilitate Business Integration Mismatch of Systems to Business Domain

Table 6.3: *ETO/MTO SME Characterisation.*

This current typology of ETO and MTO SME has been seen to struggle with the adoption and implementation of IT and specifically ERP type systems [396]. Many different systems engineering approaches have been taken in this domain, such as: internal ERP system implementation, ERP systems implementation with extensive

modifications; bespoke project planning type systems; etc, but no substantial success has been seen and implementations have been beset by widespread problems, Bertrand and Muntslag [589]. There do not appear to be cost-effective off-the-shelf solutions, comprising software and implementation methodology that comprehensively meets the business requirements of this class of enterprise. Despite a steadfast belief in the merits of IT and an eagerness to adopt new approaches such as the Internet, few of the ETO or MTO SMEs discussed within this thesis have actually realised approaching the full range of benefits on offer, such as improved delivery performance and inventory reduction. This may be mainly because of mismatches between systems requirements and readily usable IT functionality. An overview of the characterisation is presented in Table 6.3.

6.3 Requirements for ETO/MTO Strategy Deployment

In this research a process of defining new requirements was undertaken based on consolidating industrial survey, case study and workshop data together with information elicited from structured interviews. The interviews were carried out with management and technical employees from research partner enterprises. The interviews sought to establish the current business context and then to define potential improvements, both to IT functionality and the support they might provide for new and improved management strategies.

In order to be able to define common requirements for ETO/MTO SMEs wishing to realise a management region of 'Mass Customisation' it was considered by the research partners to be helpful to initially summarise domain issues and trends and the types of individual enterprise responses that have been made. This would provide a consistent viewpoint from which to better define potential ways forward.

Based on this line of thinking it was observed that there is a need for modern day ETO/MTO SMEs to:

- ❑ Focus management attention upon the core activities of the business where the enterprise has specific strengths and competitive advantage.
- ❑ Achieve rapid growth and meet the targets set by increasingly demanding stakeholders.
- ❑ Reduce the time-taken and costs required introducing new high-quality products.
- ❑ Be more flexible by being able to supply customised, just-in-time products at lowest cost.

As a response to these issues, enterprises are currently trying to:

- ✓ Achieve business excellence in their core businesses.
- ✓ Rapidly introduce and effectively market new customer specific products.
- ✓ Deliver total solutions to the customer that encompass high levels of customer service
- ✓ Grow through strategic mergers, acquisitions and alliances to reduce risk and increase overall capability.
- ✓ Operate on a truly global basis, with some manufacturing and distribution close to customers.
- ✓ Integrate supply chains regionally and globally to achieve compressed lead-times and the lowest possible cost.
- ✓ Effectively manage enterprise resource, in respect of limitations and constraints.
- ✓ Deploy IT to support business strategy and facilitate access to new electronic markets.

Additional risks that enterprises are facing include:

- 7 Political unrest and the imposition of sanctions / tariffs between trade groups.
- 7 Nation states become more or less interventionist.
- 7 Fluctuations in global currency markets.
- 7 Environment legislation.
- 7 IT security and global terrorism.

Whilst some of the efforts have been more thoroughly implemented than others, for many of the collaborator enterprises there exists a greater demand for strategy implementation focus that is enabled, rather than constrained, by the deployment of IT based systems. To minimise the effects of constraints imposed by manufacturing business systems and IT it was agreed by all research partners that for ETO/MTO SMEs a major shift in current systems design and functionality is essential. The following implicit requirements provided by Weston [471] can act as a starting point for such a paradigm shift: namely new business and supporting IT systems should possess means of:

- 1) Realising flexible and scalable connections between building blocks (human and technical) of enterprise systems, at all levels of a manufacturing enterprise.
- 2) Gaining ready access to explicit definitions of building blocks of enterprise system in terms of:
 - a) 'How' building blocks should be integrated together so that they can inter-operate with each other.
 - b) 'What' building blocks are capable of (individually and collectively) in terms of their functional capabilities, capacity to do things and likely behaviour changes when doing things.
- 3) Developing a holistic definition of what enterprise activities need to be done and in what order and by when.
- 4) Matching capabilities [of (2b) to requirements [of (3)] rapidly and effectively.
- 5) Implementing decisions made [during (4)] into actual compositions and/or re-compositions of enterprise systems, thereby as required changing the way enterprise components function and inter-operate over specified time-frames.

Even though these high-level requirements can act as a foundation for next-generation systems development the research partners agreed that a knowledge of more detailed ETO/MTO requirements is also of fundamental importance. This is necessary to specifically address more focused, practical needs and desires and to ensure means of enabling their incorporation as part of next-generation business systems design and implementation methods. An interpretation of this specific (ETO / MTO SME) need is summarised in the following three tables, which focus respectively on: business requirements; technological requirements; and general assumptions. Some of the table items concern rather abstract and conceptual thinking, but these items are included to provide a more complete picture of the overall need.

No.	New Business Requirement
1.	Deliver improvement to the overall profitability of the enterprise at minimum cost.
2.	Deliver an integrated management control framework utilising exceptions and automatic alerts.
3.	Flexibly enable the operation of key business processes that are aligned to business strategy, are measurable, support internal initiatives (quality and personnel) and can be effectively resourced within the constraints and limitations of the enterprise.
4.	Utilise flexible efficient systems, which maintain the competitive advantage of the enterprise, minimise business risk, have low variety, are scaleable and can be supported over a sufficiently long timeframe (i.e. at least 5 years).

5.	New systems must be deployable in a time-frame of less than 12 months.
6.	Provide fast, effective and efficient support for the deployment of any global trading relationship and support for mergers and acquisition activity
7.	Provide business and process integration (horizontal and vertical integration) throughout the entire supply chain.
8.	Facilitate the fulfilment of customer requirements utilising any possible sales channel throughout the entire life-cycle of the products and services supplied.
9.	Enable the process of reflecting very specific customer requirements within high-volume production processes without affecting lead-time, cost or quality. Transferring through mutually beneficial dialogue product design authority from the producer to the customer.
10.	Deliver real-time (available-to-promise) quotation, costing and production scheduling to optimise throughput, minimise inventory and increase productivity within the entire supply chain.
11.	Provide simple process modelling facilities for 'what-if' business scenarios and production simulation.
12.	Deliver relevant, reliable, accurate, timely and sufficiently well grained business intelligence for the complete business environment in which the enterprise operates.
13.	Ensure that a global view of projects, in terms of control points, progress and post implementation review is maintained.
14.	Integrate the activities of enterprise stakeholders and their multiple perspectives to achieve holistic design, development and operation and to resolve compromise.
15.	Provide education in achieving enterprise objectives rather than operations training.
16.	Ensure the retention of the best elements of enterprise identity, intellectual capital, and culture where possible, rather than enforcing any strict corporate regimes.

Table 6.4: *New Business Requirements.*

The business requirements (listed in Table 6.4) present a view of enterprise systems that are business performance driven. This view is process rather than functionally orientated with a view to achieving tighter process control and enabling agility through use of change capable IT, so as to meet a range of customer requirements.

No.	New Technical Requirement
1.	Deliver 24 hours a day / 7 days a week global operation and support with no downtime for maintenance, upgrades or re-location.
2.	Provide global multi-company, multi-site and multi-language support.
3.	New systems should be capable of both, internal and external implementation and support, within minimum resource requirements
4.	Achieve fast, effective, efficient and holistic system design, configuration, simulation testing and development using industry standards.
5.	Encapsulate and secure enterprise knowledge and intellectual capital for visualisation and reuse.
6.	Applications and enterprise system elements have zero latency throughout the entire supply chain, where the requirement for integration files and validation routines is removed. These also include CIM requirements for SCADA, LCS and MES systems.
7.	System and hardware design is such that batch processing can be removed. Backups can be undertaken on-line and additional processes such as account posting are redesigned so that no record lock restrictions are required.

8.	New systems are capable of web enablement.
9.	Individual business processes or workflows are used to replace previous modular functionally based system design and are implemented with minimum user interaction required.
10.	Item definition and storage methodologies are redesigned to remove item proliferation and data redundancy problems. Flexibility is included to allow individual items to: 1) exist in one or multiple formats (raw material, components or finished goods) and 2) have one or multiple costs attributed to them (budget, standard or actual) for different global enterprise operations, such as different country origin of manufacture or inter-company transfer.
11.	Scheduling functionality supports real-time available-to-promise concepts, i.e. combination of MRP and project planning approaches.
12.	Real-time information upon all enterprise business aspects is delivered instantaneously in acceptable formats and is capable of deeper interrogation. Functionality for both primitive (OLTP) and derived data (OLAP) is contained within the system.
13.	Data validation and consistency checking facilities are integral to the whole system, so as to enforce system and database integrity.
14.	The new system contains effective security management and secure single user sign-on and configuration capabilities.

Table 6.5: *New Technical Requirements.*

The technical requirements (listed in Table 6.5) exemplify a common need for a systems infrastructure, which is flexible, consumer facing, has high availability and scalability, low complexity, good performance and can be globally deployed and supported throughout the whole of the supply chain at minimum resource and cost.

The stated requirements for a systems infrastructure were further detailed by direct observation of research partner needs:

- Must be developed for open use within the public domain and have full life-cycle support at minimum cost.
- Must be built with respect to current IT limitations and within acceptable cost, i.e. restrictions on the utilisation of high performance servers and network bandwidth.
- Must facilitate business process-orientated design and operation of systems.
- Must be based upon emerging, enterprise engineering concepts.
- Software development must use component-based approaches and standards, where the development knowledge can be retained for subsequent redesign, analysis and implementation.
- Need to enable and support the use of a top-down, systems engineering approach.
- Must structure and support the activities of multidisciplinary and disparate teams, focusing on co-ordinating and enabling their activities, not necessarily just automating them.

The characterisation of ETO / MTO SME requirements presented within this thesis chapter, was developed to provide an abstract picture of how next-generation ETO/MTO enterprise systems might be ‘shaped’ and what additional functionality and capability (and specifically IT functionality and capability) needs to be provided in this domain. Newly developed and implemented systems, which incorporate listed capabilities should more effectively contribute to enterprise goals and deliver significantly better return on investment.

CHAPTER 7

BUSINESS STRATEGY DRIVEN IT SYSTEMS: IT ROUTE MAP

7.1 Introduction

The aim of this chapter is to introduce a Business Strategy Driven IT Systems approach suitable for ETO/MTO SMEs and to introduce and exemplify the use of an IT Route Map as a guide for the implementation of such systems. This work is essentially derived from enterprise engineering and component based systems principles as developed by Weston [148] [469] and Kosanke et al [143] [153]. But it is specifically targeted at providing ETO/MTO SMEs with a useable and uncomplicated methodology that can support enterprise-wide systems development and deployment.

7.2 Business Strategy Driven IT Systems

The literature review explained that significant value can arise from utilising a top-down approach to enterprise engineering and ongoing development and change, Kosanke et al [143]. Various public domain reference architectures have been developed to facilitate such a top-down approach. For example, CIMOSA [164], GRAI-GIM [211] and ARIS [215] methods and architectures have been proposed. However none of these claim to provide comprehensive life-cycle support and the usability of these approaches (or parts of them) must be judged on an individual basis [148]. It was further observed [141] that although these systems offer valuable assistance during fairly abstract high-level enterprise modelling and integration specification work, the resultant models can be difficult to convert from high-level strategy definitions or specifications of need to re-engineered process models into descriptions of real implementable systems. This set of observations was borne out by practical project (engineering) experiences of the author and the other research partners. Therefore it was observed that focus needs to be placed upon bridging gaps between different enterprise life-cycle phases such as by creating a methodology for linking strategy to processes models and by providing effective means by which process model execution can be achieved. In summary, Weston [148] proposes that the

following criteria should be attained before the wider utilisation and deployment of enterprise engineering concepts can be achieved.

- A. There remains a need to unify the use of a broad base of large-scale systems engineering concepts.
- B. Semi-generic reference models (e.g. in the form of exemplar models of enterprise systems, enterprise components and enterprise engineering methodologies) need to be developed to guide the application of one or more sets of concepts unified under (A).
- C. New technology (e.g. in the form of large-scale systems engineering environments) must be developed to operationalise one or more of the concepts under (A).

The concept of Business Strategy Driven IT Systems proposed in this thesis has been developed to help step through complexity issues and ease certain implementation aspects of existing public domain reference architectures and methodologies in a way that is sensitive to needs of SMEs. This Business Strategy Driven IT systems approach represents but one possible example of top-down process-orientated thinking, but in one where emphasis is placed upon the decomposition of enterprise strategy into Critical Success Factors (CSF), Key Performance Indicators (KPI) and descriptions of supporting business processes that can subsequently be 'enacted' or semi-automatically generated into new enterprise software elements. The work presented here aims to demonstrate that the large-scale conceptual enterprise engineering approaches as proposed by Weston [148] and Kosanke et al [153] can be equally applied to small-scale enterprises focussed upon a single industrial domain and provide a way forward in meeting criteria (A) and (B).

This concept has not been suggested as yet another classification of architecture and methodology, rather it builds upon proven enterprise modelling, enterprise integration and reusable software components principles. By so doing the aim is to deliver an holistic, unified and simple solution for individual enterprise domains, e.g. ETO and MTO SMEs. In essence, the Business Strategy Driven IT Systems approach can be characterised by a typology of IT, in which high-level business strategy-derived process models are used to simulate, optimise and semi-automatically generate software elements of a specific enterprise. The author considers

this to represent an improved development method for ETO SMEs a number of reasons, namely:

1. Developed IT solution(s) will exhibit alignment to business strategy, thereby providing design adequacy [427].
2. Because ETO and MTO enterprises are typically process focused.
3. Process orientation can effectively support What, How and Do classes of activity in an enterprise that cross organisational boundaries, be linked to business opportunity and need, and provide a shared enterprise visualisation from which to address inherent complexity problems.
4. Such an approach will provide an improved ability to simulate, effectively resource and optimise processes.
5. Use of underlying enterprise engineering concepts promotes the re-use of flexible software components, that potentially can be change capable, re-configurable and incur reduced system development and change lead-times. The low cost availability of standards-based, process-orientated software components could be supported by incorporation into a public domain repository. Such a repository might be developed and maintained by the UK's Central Computer and Telecommunications Agency (CCTA).
6. An underlying systems architecture can be used to support software component integration, model execution and alleviate some of the technical problems associated with current generation ERP systems and the parallel deployment of complementary IT systems. This could be loosely based around CIMOSA's integrating infrastructure concepts [162] but would also incorporate recent IT developments in enterprise application integration, web services and object-orientated programming.
7. It should provide an environment in which multi-disciplinary teams of personnel, with different business, technical and social viewpoints can effectively contribute to enterprise goals in a consistent way.

The Business Strategy Driven IT System approach developed in this research study is founded upon the GERAM framework for enterprise engineering (see Figure 7.1) and the generalised model of a process-orientated, multi-partner global business provided by an ICEIMT'97 (International Conference on Enterprise Integration and Modelling Technology) working group (see Figure 7.2).

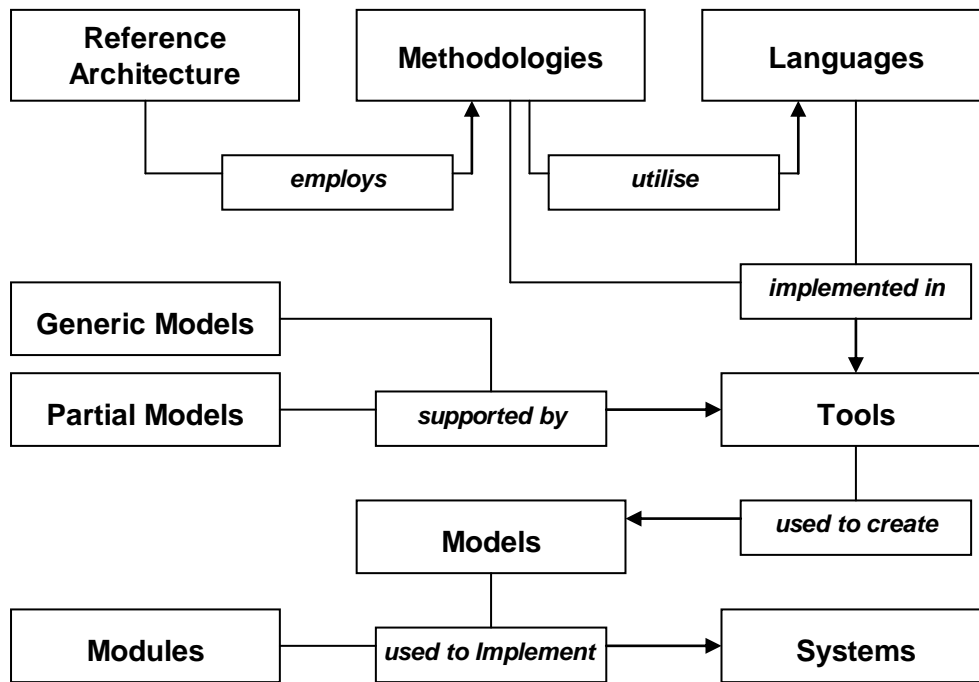


Figure 7.1: *The GERAM Framework for Enterprise Engineering & Integration [138].*

The approach provided by GERAM describes a consensus view (IFAC/IFIP Task Force on enterprise reference architectures) of the main components to be used in enterprise engineering. It distinguishes between human orientated concepts, process orientated concepts, and technology orientated concepts and defines the life-cycle and life history concepts.

The global multi-partner model provides a valuable method of visualising supply chain activities and emphasises the need to design, model and realise appropriate process and organisation streams. Furthermore, with the addition of a linkage between business strategy and process design, Goldman et al's [330] premise that 'agile competition demands that processes that support the creation, production and distribution of goods and services be centred on the customer perceived value of products...which can be linked via metrics to value-added enterprise activities from which the processes are composed', can be fulfilled. The global multi-partner model illustrates, albeit in an abstract way, the target for which software components need to be developed and resourced to enable the deployment of measurable, value-adding activity chains across organisational and national boundaries.

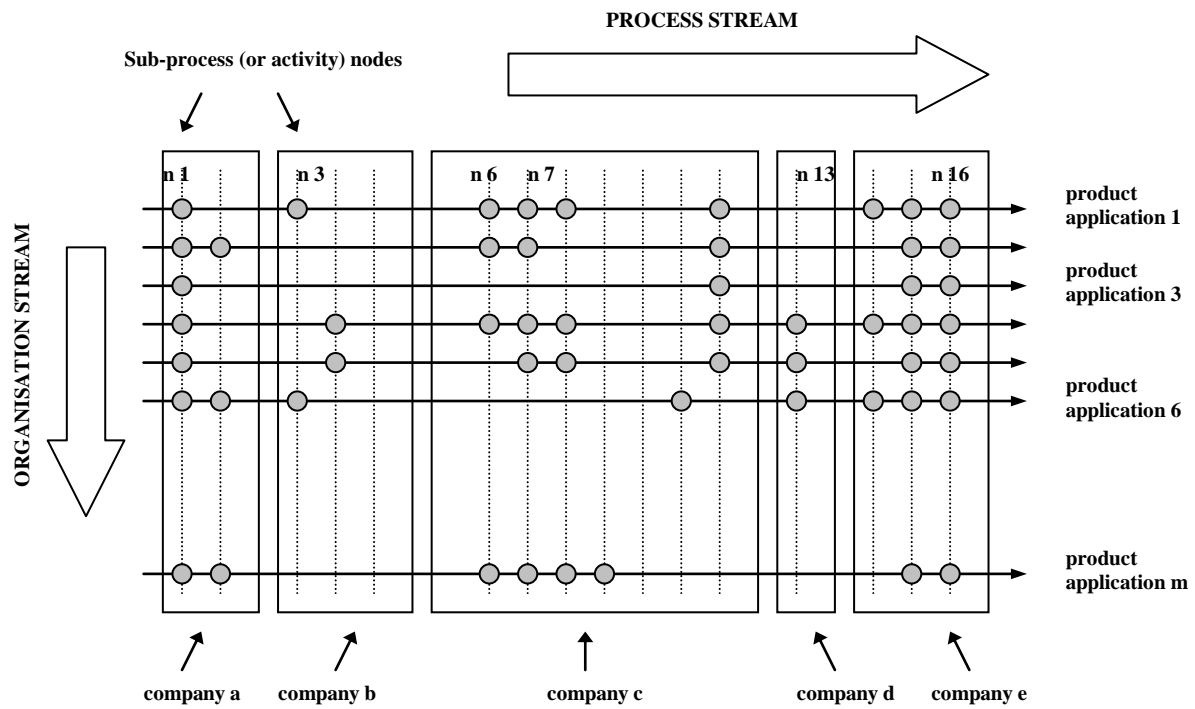


Figure 7.2: *Process and Organisation Streams* [589].

In theory the Business Strategy Driven IT Systems approach developed in this study is a partial reference architecture. In its domain of use it recommends full enterprise life-cycle support and multiple enterprise views, from which particular models and software can be specified, decomposed and implemented in a form suitable for individual enterprises. Much of its concept are equally applicable to other industry groups, i.e. other than just ETO/MTO SMEs, Figure 7.3.

The process of adopting a Business Strategy Driven IT Systems approach is illustrated in Figure 7.4 and is comprised of five main steps. These are: (1) enterprise domain characterisation and KPI / CSF definition, (2) enterprise modelling and process decomposition, (3) business model template (partial model) development, (4) systems architecture specification and (5) formation of a library of process-orientated software components. It is anticipated that professional researchers, industrial consultants and software developers would initially undertake these steps, thereby de-coupling individual enterprises from the complexities of low-level enterprise modelling, integration and software component design. The subsequent specification and implementation of a Business Strategy Driven IT System could be undertaken by a combination of local SME IT staff and their consultants as within a three stage process.

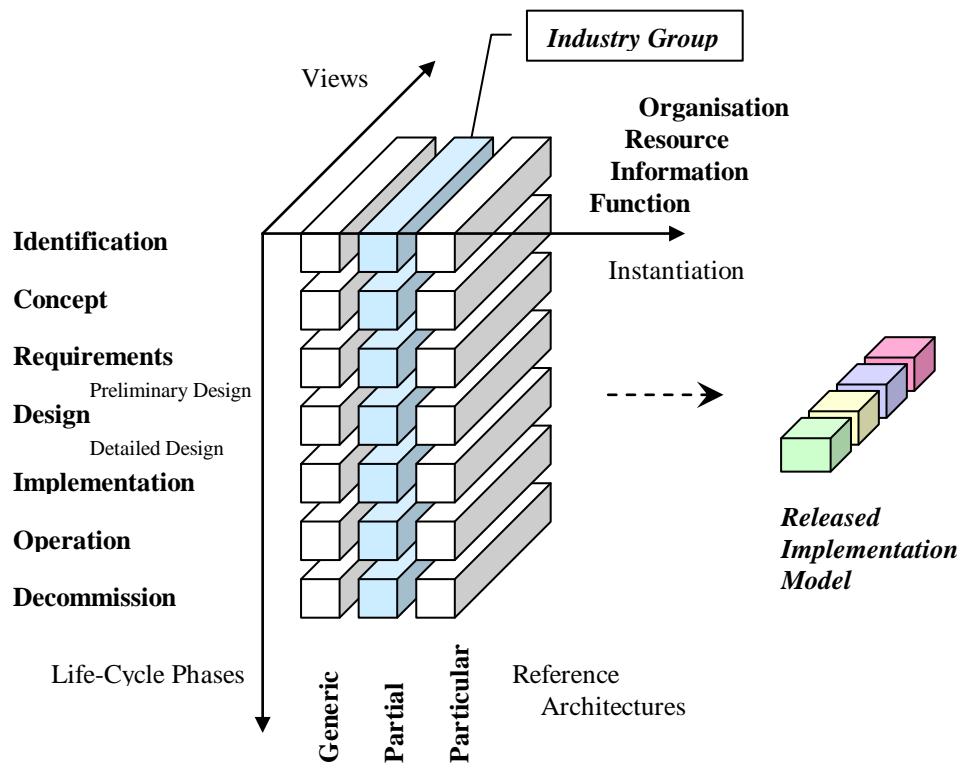


Figure 7.3: *The GERA Modelling Framework [138].*

Stage one will typically centre on selecting and installing the technical systems architecture. This will need to possess high-performance, high-availability IT capabilities provided by suitable computer networked hardware and integrating infrastructure (IIS) and enterprise-wide data repository support. Stage two will normally centre on selecting, validating and releasing process-based software components. While stage three will involve training users and going live. The purpose of the ETO/MTO Business Model Template is further detailed and discussed in Chapter 8. The proposed use of the Systems Architecture is described in Chapter 9 and the Implementation Framework and the results of a case study implementation are discussed in Chapters 10 and 11, respectively.

A choice of enterprise engineering approach needed to be made which had capabilities to structure and support the development of a business model template and subsequent process enactment, CIMOSA was found to be the most comprehensive and the best choice. This observation was supported by Aguiar and Weston [152] where it was explained that CIMOSA provides:

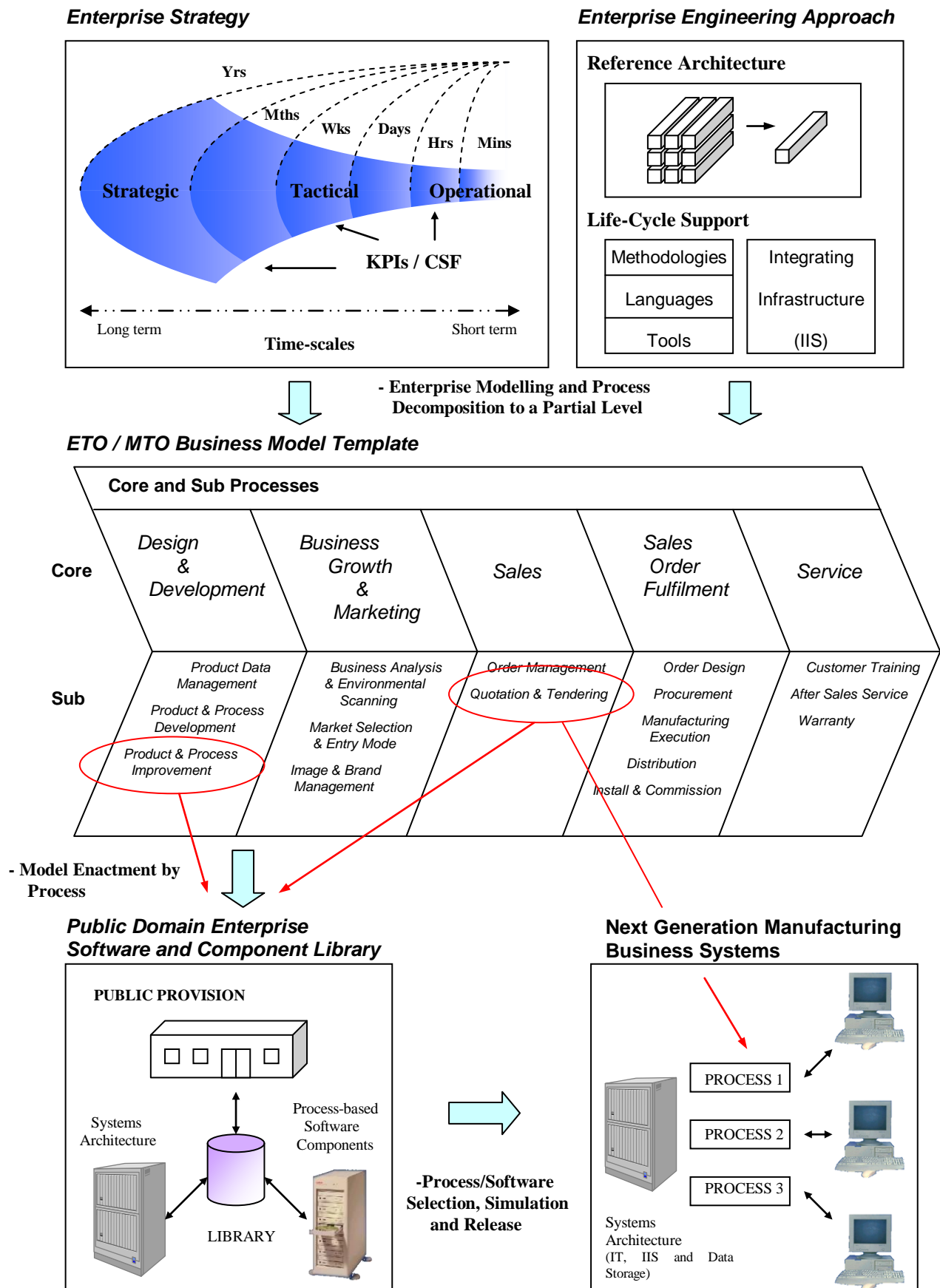


Figure 7.4: Business Strategy Driven IT Systems

- Extensive coverage of the life-cycle on an executable model basis.
- Comprehensive documentation.
- High degree of generality and openness (concerning the integration of heterogeneous IT solutions).
- An approach to modelling the behaviour of the functional entities of a particular system which, although quite mechanistic and deterministic, is quite appropriate to mechanistic activities of shop-floor control.
- Means of embracing software design and data engineering concepts and methodologies.

Instead of adopting a single approach past research work has sought to adopt 'pick and mix' framework concepts from existing public domain approaches and techniques to target their use towards the application of public domain software engineering methodologies that support the design and construction of distributed component-based systems [584].

A potential problem with this, is that it would be difficult to package together an unified approach, comprising documentation and software support, which can be delivered to and actually used by individual enterprise personnel, rather than a set of experienced researchers. Additionally, current enterprise engineering approaches and proposed standards exhibit a lack of consistency regarding their definition of life phases and views. For example CIMOSA and ENV 12204 define modelling constructs for three life-cycle phases, i.e. requirements definition, design specification and implementation description, whereas the GERA modelling framework (Figure 6.3), proposed to CEN, represents seven life-cycle phases. ISO 14258:1998 suggests the use of three life phases, namely: plan/build, use/operate recycle/dispose phases. Together with their description of different relationships governing life-history (as opposed to life-cycles) the whole subject of enterprise engineering can be potentially far too confusing and complex for the SME community. This is not in their best interest.

By insulating SMEs from any consideration of abstract concerns about enterprise engineering techniques and providing them with a business model template and associated process-orientated software components, it should become feasible for newly trained practitioners to readily configure and deploy next generation business systems and thereby solve some of the problems typically associated with

contemporary ERP packages. The design of individual software components in this respect should better facilitate, strategic alignment, process-based performance monitoring and industry benchmarking, multi-site / multi-language systems operation, workflow and staff flexibility. Software components could be large or fine grained depending upon the complexity of the process they aim to emulate and be available in multi-languages, with particular versions and possess additional attributes, such as process instructions and references to quality standards, to encapsulate specific enterprise knowledge.

The creation and proliferation of partial business model templates, process-orientated software component libraries and underlying systems architectures should naturally lead to the consistent specification and development of standards that contemporary ERP vendors and systems builders may reference when building larger-scale systems. To enable Business Strategy Driven IT Systems engineering in the manner described within this chapter, it is necessary to specify (and evolve the specification of) a formal framework of: component standards; meta-data definitions; and modelling constructs that formally describe how software components can be derived from models as needed.

7.3 IT Route Map

The notion of using an IT Route Map was developed within this study. The identified purpose of this map was to enable the implementation of Business Strategy Driven IT Systems and subsequently to facilitate learning from the viability of different solutions to known problems involved in the deployment of ERP systems within ETO/MTO SMEs. The long-term aim was thereby to increase the success potential of next generation deployments. Currently ERP systems implementation is generally considered to be within the remit of established approaches from systems vendors and associated consultancy companies, such as JD Edwards, SSA, Accenture and KPMG. But as explained within the literature survey, these general methodologies are not considered (by the research consortium and by many other SMEs) to be applicable to SMEs and this type of component-based approach due to, a) their inextricable links with current, modularly focussed ERP systems and b) their inherent complexity, long lead-times and generally high cost. Additionally, enterprise engineering research [138]

[148] is more generally concerned with overall modelling and integration concepts and standards rather actual implementation techniques. A summary overview of the IT Route Map procedural steps and artefacts is presented in Table 7.1.

IT Route Map Section	Procedural Steps	Artefacts
Business Model Template	<ol style="list-style-type: none">1. Select industrial domain, participant enterprises and define scope, responsibilities and life-cycle.2. Select enterprise engineering tools and standards.3. Undertake strategic business and IT modelling (AS-IS).4. Develop industrial characterisation and requirements.5. Define semi-generic business strategy, performance metrics, process structures and resources, based upon best practice (TO-BE).6. Produce framework for enterprise control and risk assessment.7. Produce partial models for strategic, core/sub and resource business processes.8. Validate and catalogue new semi-generic model.9. Enact model into process-orientated software components, test and release.10. Produce training literature.11. Package and document Business Model Template assets.	<p>Project plan and domain context. Tool and standards library. Systems Analysis. Domain classification. Workshop review documentation.</p> <p>Business control framework.</p> <p>Process models.</p> <p>Template signoff. Software component library.</p> <p>Training documentation. Domain repository.</p>
Systems Architecture	<ol style="list-style-type: none">1. Application environment and performance specification.2. Choice of system design and build tools.3. Application system manager development.4. IT technical infrastructure hardware and network design.5. Data repository specification and development.6. Business, information, presentation, and common services support.7. Component configuration and runtime control.8. Testbed design and release of application software.9. System version control, maintenance and retirement.	<p>Technical specification. System delivery pack. System manager interface. Design specification. Data and access definitions. Integrating Infrastructure.</p> <p>Implementation control. Architecture signoff. Control documentation.</p>
Implementation Framework	<ol style="list-style-type: none">1. Migration opportunity review.2. Systems assurance and attainment of business pre-requisites.3. Project definition and planning.4. Implementation preparation and system install.5. Particular model generation.6. Software component specification / prototyping / simulation.7. Development and confirmation.8. System integrity and stress checking.9. Implementation and training.10. New system operation, support and service level definition.11. Post implementation review and audit.	<p>Project mandate document. Scope documentation. Project initiation and plan. Technical assessment report. Process models Component specification. Component signoff. System signoff. Readiness review. Service level agreement. Audit report.</p>

Table 7.1: *IT Route Map*

The key to successful systems development and implementation is how well an enterprise can (1) react to the changing business environment (2) align IT with business strategy, (3) perform systems integration and (4) project manage the whole process and resources [560]. Software programming and installation on their own are no longer the central issues. The IT Route Map presented here represents a semi-generic enterprise engineering methodology and is comprised of three sections, namely

a 'Business Model Template', a 'Systems Architecture' and an 'Implementation Framework'. The three components of the IT Route Map components can be viewed in Figure 7.5.

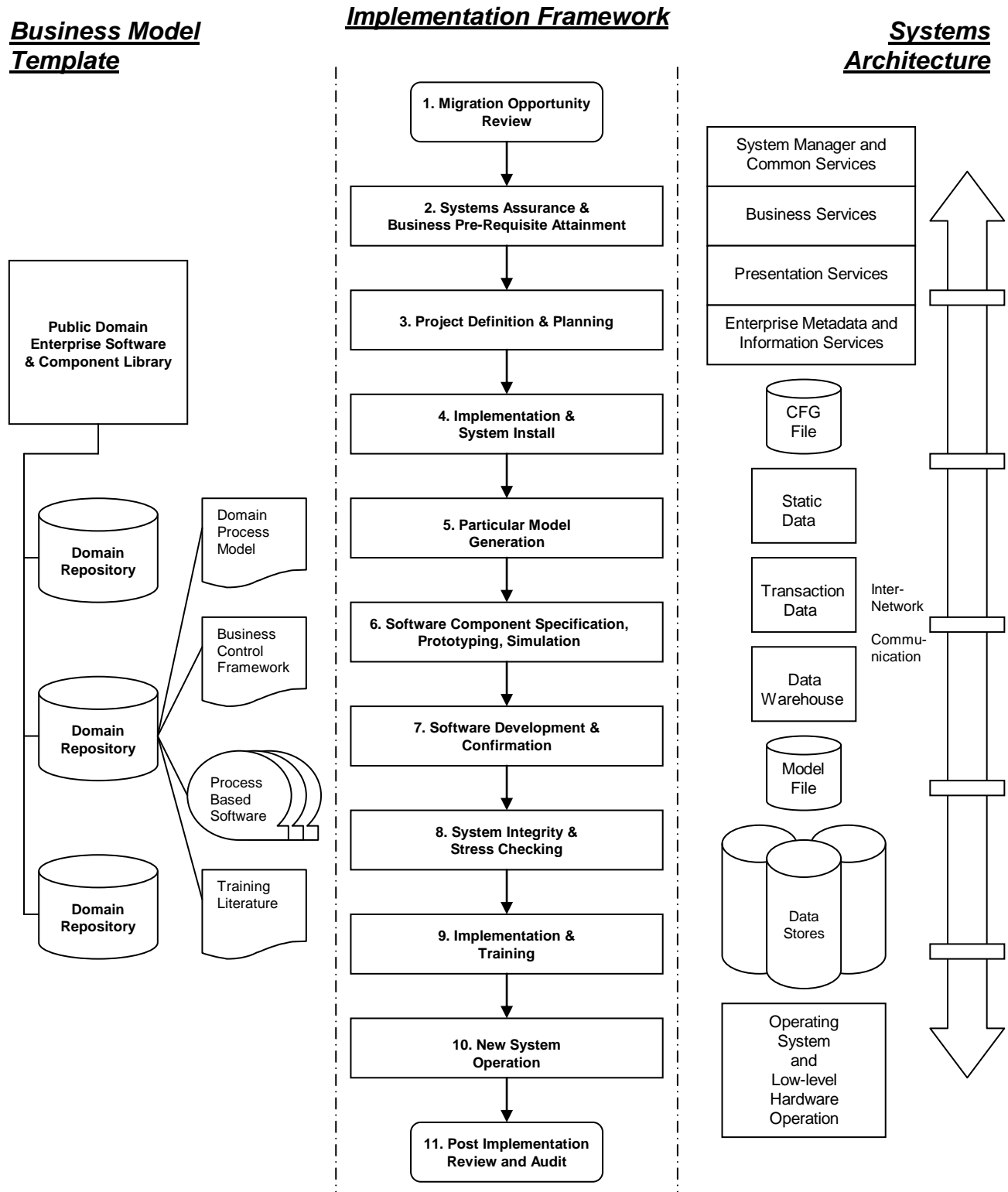


Figure 7.5: IT Route Map Development and Implementation

The Business Model Template provides a conceptual representation of how candidate enterprise engineering tools and standards could be utilised to deliver a reusable domain repository [556] comprising assets. I.e. process models, a business control framework, process-based re-configurable software components and associated training literature.

The process models would comprise the key element of the repository and would represent core and sub business processes, support generic enterprise strategies and encompass associated performance metrics, transaction information and resources. The business control framework would provide users with a generalised understanding of the need for control and risk assessment in respect of implementing a process-orientated enterprise structure. The software components, designed upon the process models and associated definitions, would allow users to semi-automatically configure flexible integrated systems, thereby reducing system development time and cost. The training literature would be provided to enable any users of the domain repository to understand and implement its concepts quickly and effectively.

Overall it is anticipated that completed domain repositories would have open access and be supported by a body such as The UK's Central Computer and Telecommunications Agency (CCTA).

The Systems Architecture is currently based on the design of an IT infrastructure upon which the implementation of the Business Model Template's configurable software components could be founded. The Systems Architecture would comprise all the necessary software, hardware and networking elements to support agile and effective, process-based enterprise operation. The design of the systems architecture, whilst largely conceptual at this moment in time, would combine emerging technologies, such as IIS [3] [164] or computation infrastructures [469] [601], with specific domain requirements to deliver a business system that would support high levels of integration and perform close to real-time systems principles [594]. Additionally, the architecture would be designed to facilitate local or globally focussed software component configurations.

The Implementation Framework has been designed to present an itemised overview of the procedures, actions and artefacts required to successfully implement a Business Strategy Driven IT System. The eleven stages of the Framework are aimed at

providing full enterprise life-cycle coverage [152] and combined together represent, what is perceived by the author to be a 'fast-track' approach to manufacturing business systems implementation. The utilisation of such a structured approach in this way, based upon recognised best practice such as the CCTA's Prince2 project methodology [603], is recognised as a route more likely to guarantee a successful system implementation, rather than a failure [540].

The key elements to gaining the maximum benefit from such a system deployment are recognised as, 1) being able to successfully being able to deal with change [97] and 2) choosing the most appropriate time to implement. The optimum time suggested by Kotter [101] is towards the limit of proven practice. I.e. not everyone is using the strategy or technology and it has minimum risk associated to it with potentially maximum return.

The next three thesis chapters, are dedicated to building upon the structure of the IT Route Map and explaining in greater detail each of the its constituent parts. These comprise Chapter 8 - Business Model Template, Chapter 9 - Systems Architecture and Chapter 10 - Implementation Framework.

CHAPTER 8

BUSINESS MODEL TEMPLATE

8.1 Introduction

This chapter details the development of a re-useable, process-orientated Business Model Template to act as a reference for SMEs that operate ETO/MTO strategies. This approach represents the author's closest interpretation of how in the future SMEs may proceed to efficiently specify, design and develop next-generation manufacturing systems. The foundation of this proposal is based primarily upon first-hand industry experience, elicited collaborator requirements, research analysis work and real IT project development activity.

Whilst, the design of the Business Model Template approach provided here is largely at a high conceptual level, it is anticipated that the themes presented here should provide enough substance from which to undertake part evaluation within a case study implementation. At this stage of template development it would be impractical, due to thesis time-constraints, to analyse, model, document and program the ETO/MTO SME domain in full.

The Business Model Template would comprise of assets that could be maintained within a public domain repository and supported by a body such as the UK's CCTA (Central Computer and Telecommunications Agency). The potential storage and sharing of assets in this way could assist SMEs in achieving reduced system licensing costs and software development lead-times, by being able to more freely select previously designed domain models and software components. Although it is likely that some financial charge would have to be made to support the public provision of this 'Domain Repository' (Figure 8.1). This charge would possibly be considerably less, due to the large numbers of willing SMEs in the UK's business community [15], than typical costs associated with ERP systems from vendors such as JD Edwards, Oracle and SAP.

The assets of the Business Model Template would consist of a business control framework (an integrated tool to aid enterprise management decision-making), process models, a software component library and associated training and quality

documentation. The construction of the template could be enabled through the use of enterprise reference architectures, to enable effective modelling and integration life-cycle support. This would assist in the development of standard approaches, model reuse and more rapid application development.

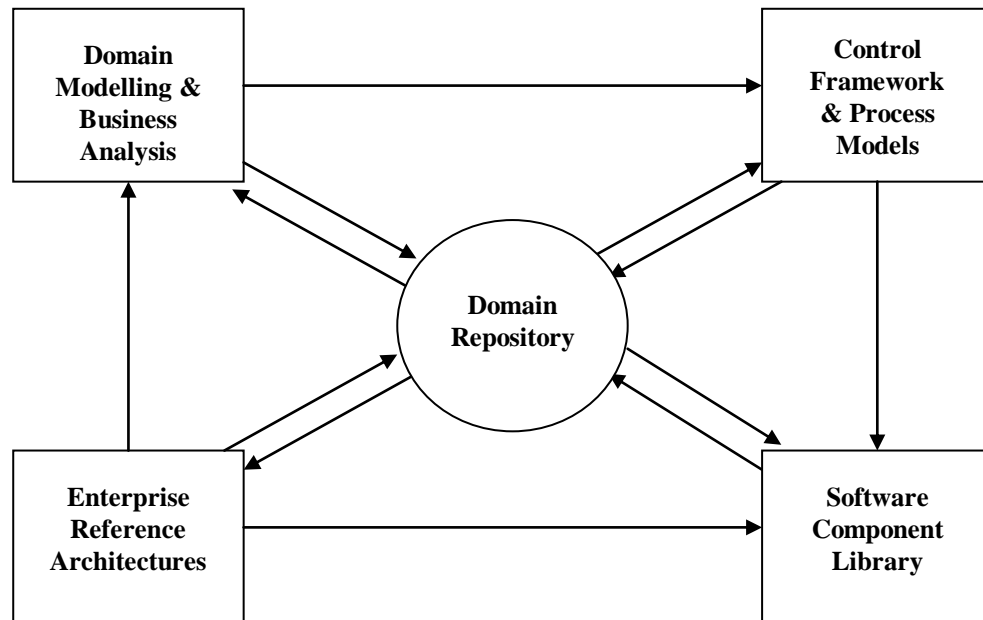


Figure 8.1: *Business Model Template Development, modified from [556].*

8.2 Template Development

The initial development of the template requires constructing a semi-generic business model that reflects solutions to the problems of the industrial domain and effectively addresses concerns related to resource constraints. Such a Business Model Template development process can be seen to comprise of 11 stages (see Table 7.1) and is further illustrated in Figure 8.2. The first stage represents the choice of industrial domain and the establishment of a project scope, context and plan for developing the new template. The selection of enterprise tool and associated standards are required to lend structure to the whole Business Strategy Driven IT System approach. This is particularly important to ensure that the various parties involved in the enterprise engineering activities operate in a consistent and timely way and the reuse of previous models and solution fragments is promoted. Whilst, it has been established [148] that no one public domain enterprise engineering approach covers all enterprise modelling and integration aspects, use of the CIMOSA architecture [165] and a pick-and-mix approach to the use of enterprise modelling tools adopted by Weston et al [572] is

recommended by the author. This would remain valid until such a time that one unified, simple to use and low risk enterprise engineering approach and supporting modelling tools is developed.

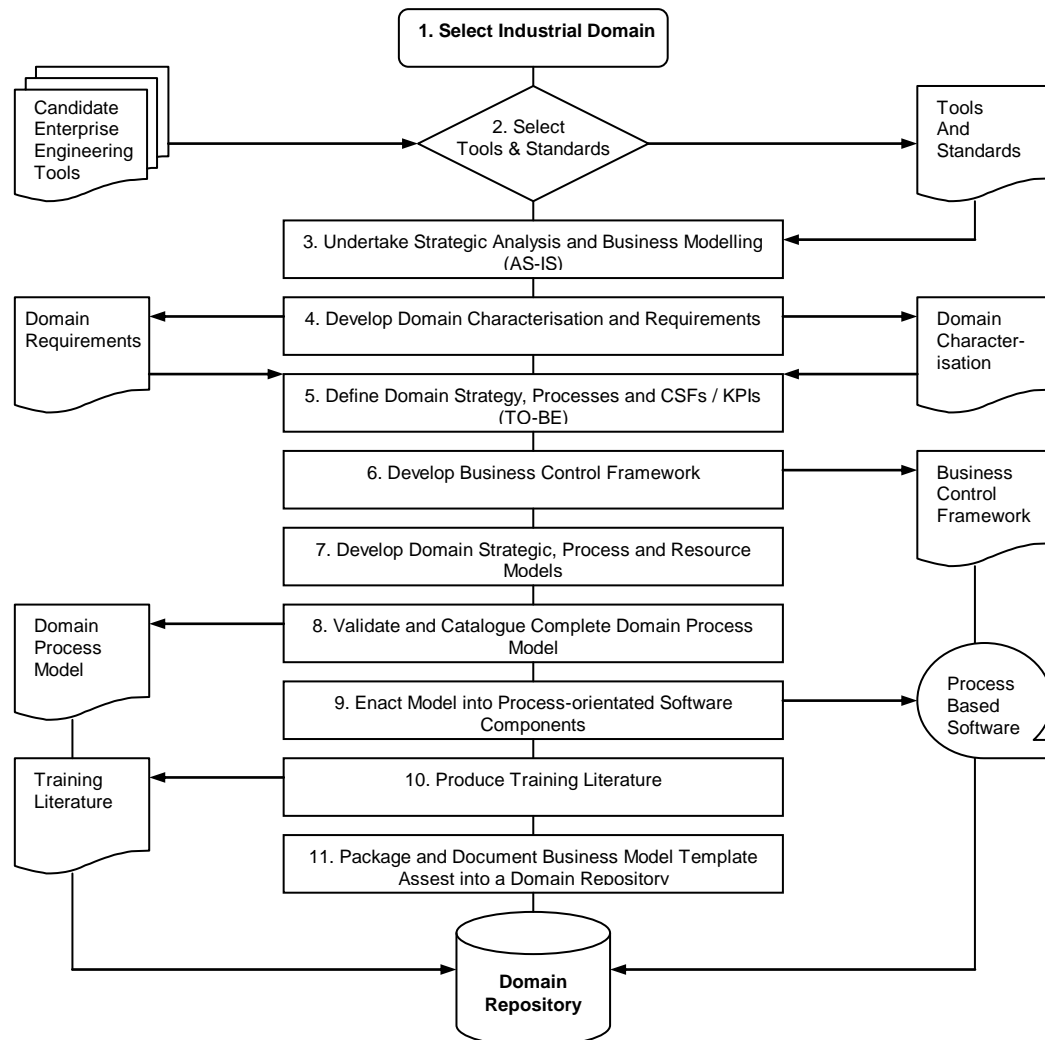


Figure 8.2: *Business Model Template Development Procedures.*

An analysis of the choice of domain strategy, business process and IT analysis can be undertaken in a number of ways and suitable choices will be largely dependent upon the study scope and the choice of modelling tools, such as IDEF [182] or SSADM [582]. A prime requirement is the attainment of approach consistency and life-cycle coverage across all enterprises undergoing analysis in a domain. Only in this way will effective comparison between common requirements and solutions be achieved. Once the analysis based on 'AS-IS' modelling has been completed, certain properties of the domain can be characterised. This can lend structure to the preparation of a detailed description of the domain in terms of: competitive landscape; strategic perspectives;

enterprise characteristics; products and services; generic business processes; employed methodologies and systems; together with new domain requirements, etc. The remaining stages comprise the construction of the Business Model Template and are covered in the next four thesis sections.

8.3 Business Control Framework

This business control framework is aimed at providing IT Route Map developers and users with an understanding of the need for enterprise controls and risk assessment in respect of process-based enterprise operation. The recommended framework encompasses three levels of management activity needed to determine the competitive position of the enterprise and its capability with respect to environmental control. The management activity proposed includes: Strategic Vision Development, Business Management and Process Audit (see Figure 8.3).

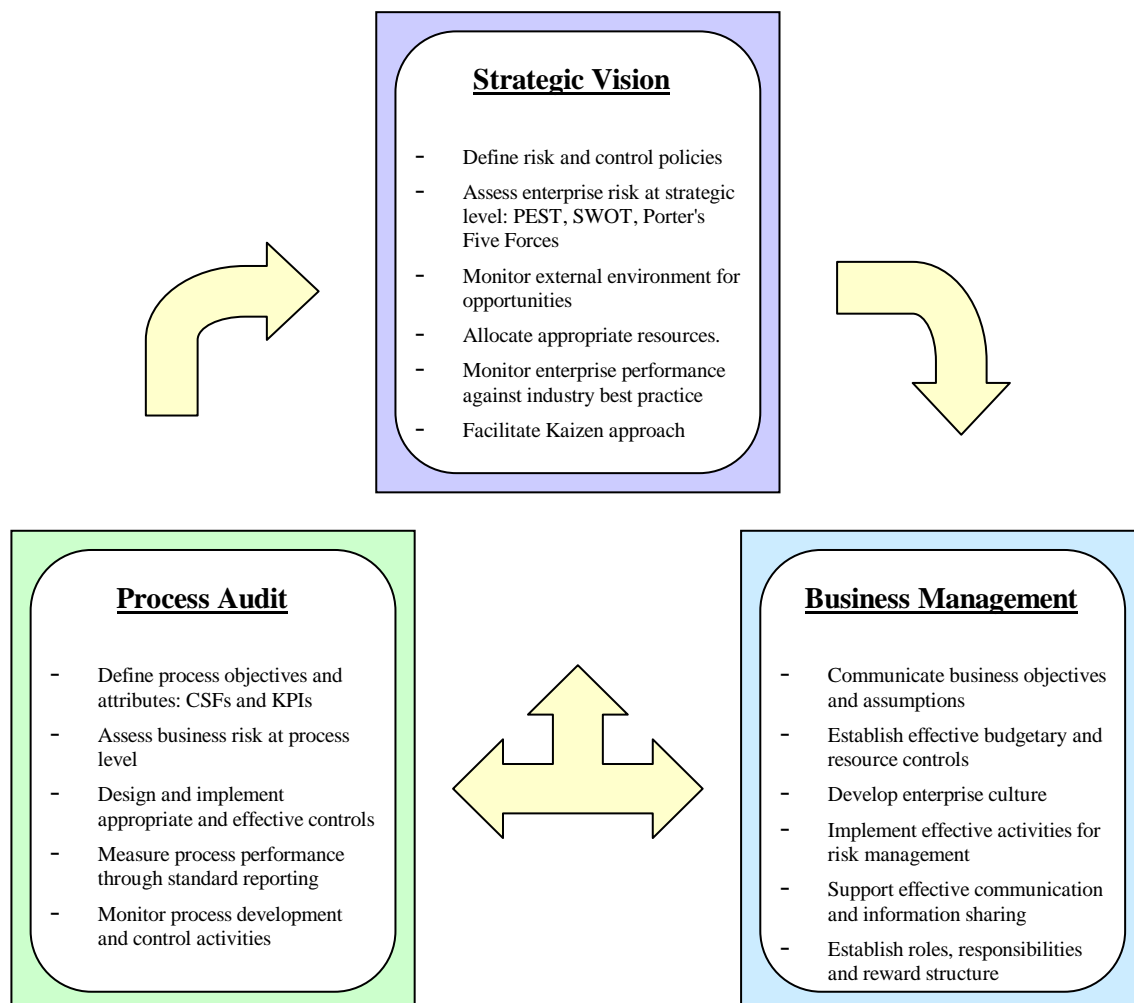


Figure 8.3: *Business Control Framework.*

The Strategic Vision should be developed to portray a set of activities that would be integrated into the strategic management process of the enterprise, in order to (a) understand the effect of external and internal factors on the enterprises and its strategy, (b) define the industrial environment and required control behaviours and (c) align the enterprise's organisation with its developed business strategies.

Business Management activities should establish the link between strategic control and process controls and are required throughout the enterprise in order to effectively identify, assess and react quickly to business risks that can prevent the enterprise from achieving its strategic and business objectives. Process Audit activity should allow enterprise personnel and in particular, process owners to continuously identify, monitor, respond and prioritise actions needed to meet changing business requirements, both internally and externally to business processes.

The utilisation of this business control framework should assist enterprise management to make decisions regarding suitable enterprise control activities and business risk. By having such a framework in place the enterprise should be able to exhibit a greater degree of control over its industrial environment and be in a better position to quickly react to business opportunities or threats.

8.4 Process Model Design

At this stage of enterprise engineering, the Business Model Template is used to structure the use of a top-down approach to (TO-BE) process model development for ETO/MTO SMEs. Focus is on developing process models at three levels, at which prime attention is on realising (1) business strategy, (2) core business operations and (3) suitably organised sets of resource systems.

To help guide this process model development procedure, a semi-generic model was developed from the domain characterisation detailed within Chapter 6 and partially validated by the research collaborators through their participation in workshops. In respect of the thesis work developed here, the term 'semi-generic model' is used to represent a partial or medium-grained perception of an industrial sector or business domain. Using the instantiation layer principles defined by CIMOSA [3] and with specific regard to the subject matter of this thesis the following could be seen to apply:

- A generic layer would contain process building blocks and building block types as the elements of the modelling tools/languages to express any high-level model, i.e. applicable to any manufacturing enterprise.
- A partial layer would contain libraries of semi-generic or partial models classified by industry sectors and used in particular models, i.e. ETO/MTO SME domain.
- A particular layer would contain particular models, i.e. a specific model of an individual ETO/MTO SME or any subsequent part thereof.

The developed semi-generic model is illustrated by Figure 8.4. The decomposition of process elements suggested by this semi-generic model was abstracted from an understanding of: (i) common strategic characteristics found within each participant enterprise, (ii) key business objectives and (iii) knowledge typically acquired during review of current (AS-IS) business process configurations in partner SMEs.

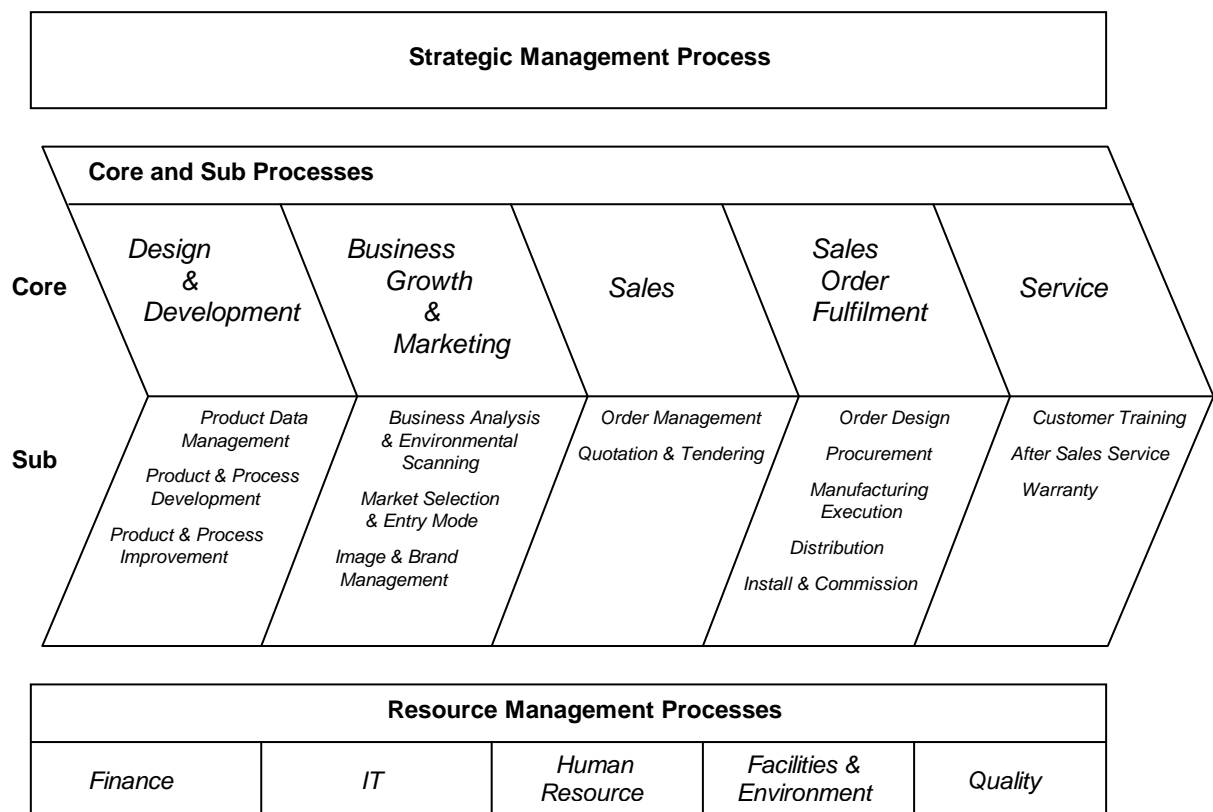


Figure 8.4: *Suggested ETO/MTO SME Business Processes Decompositions.*

Whilst it is recognised that the defined business model represented by the semi-generic model could have been produced by utilising a recognised enterprise architecture and

reference methodology such as CIMOSA, previously available public domain approaches were considered to be overly centred on technical issues (rather than business ones) and in general are probably too complex, costly and time-consuming for SMEs to undertake. Hence the suggested preferred route of utilising a standard template, which leads to a simplistic representation of business process and is therefore likely to be accepted by SMEs as a useful means of adopting emerging enterprise engineering concepts and techniques. This work was developed as an extension of the author's previous work on business process representation and Intranet development [113], notation used by KPMG for business process measurement, Kelly [591] and an approach for supporting business process management as devised by Thompson and Redstone [626].

The exemplar standard template constructed and developed as part of this study consists of 20 dimensions that collectively cover common Strategic, Process and Resource concerns found within the study domain (Table 8.1). These dimensions were selected to:

1. Provide an easy to understand representation of process and activity flows.
2. Focus enterprise activity upon strategy and business objective accomplishment.
3. Enable exception based management reporting targeted at the CSF and KPIs.
4. Establish clear definitions of responsibilities.
5. Provide a base for resource analysis in terms of skills and competencies.
6. Assist in standards compliance, such as ISO900 and IIP, together with health and safety regulations.
7. Ensure conformance with enterprise reference architectures, e.g. CIMOSA's identifiers and modelling constructs.

Whilst the template developed here would be of benefit to SMEs in a number of ways, (i) improved consistency for process documentation, (ii) high visibility of established best practice and (iii) its inherent focus upon business strategy, it could still have criticisms placed upon it. Primarily, it could be commented that its use could lead to the erosion of competitive advantage, through competitor enterprises conforming to the same business model and practices. This problem though, would only exist if the implementers of the model chose not to refine it to the specific, strategy and

operational needs of the individual development enterprise, i.e. the creation of a particular model from the base semi-generic model.

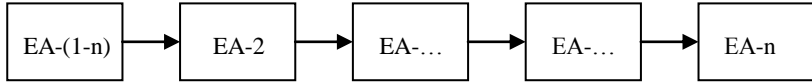
Process Dimensions	Dimension Description
Name	Common name of the process.
Identifier	Unique identification code, i.e. DP-1 = Domain Process one, BP-1 Business Process one.
Version	Version number.
Date	Process release date.
Description	Process summary.
Owner	Who has design authority for the process.
Objectives	Process are designed to serve a specific business objective. Their customers may be internal or external to the enterprise. Processes must be SMART, i.e. Specific, Measurable, Attainable, Realistic and have a relationship to Time.
Inputs	The inputs to the process represent the elements, materials, resources and information required to complete the necessary activities.
Activities	<p>The enterprise activities that produce outputs for the processes. Identified EA numbers.</p>  <pre> graph LR A[EA-(1-n)] --> B[EA-2] B --> C[EA-...] C --> D[EA-...] D --> E[EA-n] </pre> <p>Arrows may be omitted to represent non-sequential enterprise activities</p>
Outputs	The outputs represent the end result or deliverable of the process or activity chain.
Systems	The collection of resources to accomplish the process objectives, such as IT or mechanical or paper based systems.
Transactions	Transactions represent data and information, related to business intelligence and are broken down into routine, non-routine and financial components.
Risks	Risks that may reduce the achievement of process objectives.
Controls	Implemented policies and procedures to reduce, transfer or avoid the process risks.
CSFs	Critical Success Factors that support the process objective
KPIs	Key Performance Indicators to measure process performance, trending and benchmarking.
Competence Level	Levels of skills and training pre-requisites to operate and manage the process.
Standards Compliance	References to associated enterprise and industrial standards, such as ISO 9000 and Investors in People.
Problem Areas	Symptoms of poor performance or likely issues that may stop the process from operating at its most effective level.
Kaizen	Continuous improvement opportunities and potential development areas.

Table 8.1: *Standard Process Template.*

The standard process template proposed could be seen as covering an inverted hierarchy of business concerns, i.e. CSFs and KPIs that flesh out the strategic vision of the industrial domain populated by the case study ETO/MTO SMEs. To demonstrate how the process template approach might be applied, example semi-generic process models were initially developed by the author (Appendix D) based upon earlier model abstraction work. Using these examples as foundation, research collaborators were then tasked with constructing particular or specific models for their own individual enterprise. A comparison of the semi-generic 'Sales Order Management' process model example and a user-derived template for the Tritex International Ltd. enterprise can be seen below (Table 8.2).

Process Dimensions	Base Semi-generic Model	User Derived Particular Model
Process Name	Sales Order Management	Sales Order Management
Identifier	BP-1	BP-1
Version	1.00	1.00
Release Date	2/4/2000	N/A
Owner	Sales Director	Sales Manager
Description	The timely receipt of sales order information, accurate sales order entry and effective customer management.	The timely receipt of sales order information, accurate sales order entry, pricing, and effective customer management.
Objectives	1. To achieve customer order fulfilment and maximise customer delight. 2. Provide flexibility for order changes. 3. Plan customer order in terms of capacity. 4. Optimise cash flow.	1. To achieve customer order fulfilment and maximise customer delight. 2. Provide flexibility for order changes. 3. Plan customer order in terms of capacity. 4. Optimise cash flow. 5. Undertake accurate pricing.
Inputs	<ul style="list-style-type: none">• Customer Purchase Order / Contract• Customer Details / Credit Check• Marketing Forecast• Product Specifications• Manufacture / Purchase Lead-times• Cost Estimate• Quotation	<ul style="list-style-type: none">• Customer Purchase Order / Contract• Customer Details / Credit Check• Product Specifications• Guaranteed Product Performance• Manufacture / Purchase Lead-times• Cost Estimate• Quotation
Activities	EA-1 Design, Assembly and Manufacture Validation. EA-2 Order / Customer Entry. EA-3 Capacity Check and Scheduling. EA-4 Order Acknowledgement. EA-5 Sales Order Release. EA-6 Delivery and Cash Management.	EA-1 Design, Assembly and Manufacture Validation. EA-2 Order / Customer Entry. EA-3 Capacity Check and Scheduling. EA-4 Order Acknowledgement. EA-5 Sales Order Release. EA-6 Delivery, Transport Planning, and Cash Management.
Outputs	<ul style="list-style-type: none">• Customer Delivery Schedule• Cash Flow Planning	<ul style="list-style-type: none">• Cash Flow Planning• Revised Sales Forecast

	<ul style="list-style-type: none"> • Revised Sales Forecast • Design Requirements • Assembly Requirements • Manufacture Requirements • Shipping Requirements 	<ul style="list-style-type: none"> • Design Requirements • Assembly Requirements • Manufacture Requirements • Shipping Requirements
Systems	<ul style="list-style-type: none"> • Order, Forecasting and Scheduling Systems • CAD and Technical Documentation • MRP • APS 	<ul style="list-style-type: none"> • Order and Scheduling Systems • CAD and Technical Documentation • MRP and Finite Scheduling
Transactions	<p>Routine</p> <ul style="list-style-type: none"> • Letters of Credit • Advance Payments • Order Details <p>Non-Routine</p> <ul style="list-style-type: none"> • Logistics Contracts • Agency Fees and Royalties <p>Finance</p> <ul style="list-style-type: none"> • Credit Checking • Dunning Status 	<p>Routine</p> <ul style="list-style-type: none"> • Letters of Credit • Advance Payments • Order Details <p>Non-Routine</p> <ul style="list-style-type: none"> • Logistics Contracts • Agency Fees <p>Finance</p> <ul style="list-style-type: none"> • Credit Checking
Risks	<p>A. Order Changes without Penalty (1,2,3)</p> <p>B. Product Availability (2,3,4)</p>	<p>A. Order Changes without Penalty (1,2,3)</p> <p>B. Product Availability (2,3,4)</p> <p>C. Customer Payment Difficulties (4)</p> <p>D. Late Product Delivery (4)</p>
Controls	<p>⇒ Letters of Credit</p> <p>⇒ Order Administration (A)</p> <p>⇒ Production Planning and Scheduling (B)</p>	<p>⇒ Letters of Credit</p> <p>⇒ Order Administration (A)</p> <p>⇒ Production Planning and Scheduling (B)</p>
CSFs	<ul style="list-style-type: none"> • Shortest time period for order entry (1,3) • Flexibility to respond to order changes (2) • Effective cash billing and collection (4) 	<ul style="list-style-type: none"> • Shortest time period for order entry (1,3) • Flexibility to respond to order changes (2) • Effective cash billing and collection (4)
KPIs	<p>⇒ Fast order fulfilment cycle</p> <p>⇒ Flexibility of non-standard orders</p> <p>⇒ Monies outstanding</p>	<p>⇒ Fast order fulfilment cycle</p> <p>⇒ Flexibility of non-standard orders</p> <p>⇒ Monies outstanding</p> <p>⇒ On-time Delivery</p>
Competence	Level 3 Sales Clerk	N/A
Standards	ISO9000, 4.3, 4.5	Company Manual: Section 4 Contract Control
Problems	<p>7 High costs of sales process</p> <p>7 Poor manufacturing performance to plan</p> <p>7 Inaccurate product specification</p>	<p>7 High costs of sales process</p> <p>7 Poor manufacturing performance to plan</p> <p>7 Inaccurate product specification</p> <p>7 Inaccurate costing</p>
Kaizen	<ul style="list-style-type: none"> ✓ Supplier Involvement ✓ Implementation of ATP 	<ul style="list-style-type: none"> ✓ ISO 9000 ✓ Supplier Involvement ✓ Move to semi-standard products with modifications made at the latter stages of manufacture (Perceived Differentiation).

Table 8.2: Sales Order Management Process Comparison.

Using the template as a basis Tritex International employees only chose to modify the semi-generic template slightly and generally agreed it was a reasonably accurate representation of its sales order management process. The main differences that could be viewed were: (1) the enterprise did not undertake any forecast activities; (2) they felt that accurate and profitable pricing was a key business objective; (3) sales contracts regularly had guaranteed performance criteria built into them (4) a high risk for the enterprise was the non-payment or late cancellation of products. This had occurred a few times in recent years and had placed a large burden upon the financial position of the enterprise.

Whilst, the research collaborators concurred that the provision of a document comprising the full range of business process models would be useful to their own enterprise, based upon what they had seen thus far, concerns were raised about the actual meaning of some of the template's terminology. It was suggested that the development of a glossary would prove useful.

A fully documented ETO/MTO SME model would represent an encapsulation of domain characteristics that could be referred to by 'enterprise engineers' responsible for domain SMEs (and thereby can adopt good enterprise engineering practice and at reduced cost, i.e. with less time and effort and by making less costly mistakes when designing, changing or re-engineering enterprise structures).

8.5 Process Model Enactment

Having developed a suitable set of process definitions, it is necessary for SMEs to operationalise those definitions in the form of real executable systems, i.e. to facilitate the enactment of process models as software components that interact effectively with their human users. With respect to this stage of enterprise engineering the Business Model Template was developed to enable the processing of computer executable process models, so as to facilitate the semi-automatic development of flexibly integrated software components.

Whilst modular systems in the form of re-configurable electro-mechanical components have been developed and used industrially for a number of decades, it is only recently that this type of approach has come to be supported by suitable software product developments. Recent advances in software component technologies are due

to the increased availability of a) object-orientated system design techniques and b) advances in distributed systems technology (such as the availability of general purpose computation integration infrastructures like the Web, Fieldbuses, CORBA and Java Beans/Studio) [558].

Previous approaches to model enactment have centred upon the use of IIS techniques as provided by CIMOSA [3] and CIM-BIOSYS [248], but these require very detailed model design work. The SEW-OSA workbench developed by Edward et al [141] presents a more realistic approach for SMEs to take. Potentially it can be operationalised by a formal systems engineering workbench that combines CIMOSA, generalised stochastic time Petri-nets, predicate-action Petri-nets, object orientated design methods and the services of a computer infrastructure, such as CIM-BIOSYS. Earlier work at Loughborough University had led to the SEW-OSA workbench which provides a model enactment capability that allows design model manipulation through process and IT system simulation, rapid prototyping and physical system implementation of software components. The Meta-Lifecycle Model described by Baudoin and Hollowell [593] represents a similar 'build-to-suit' methodology for software development, Figure 8.5.

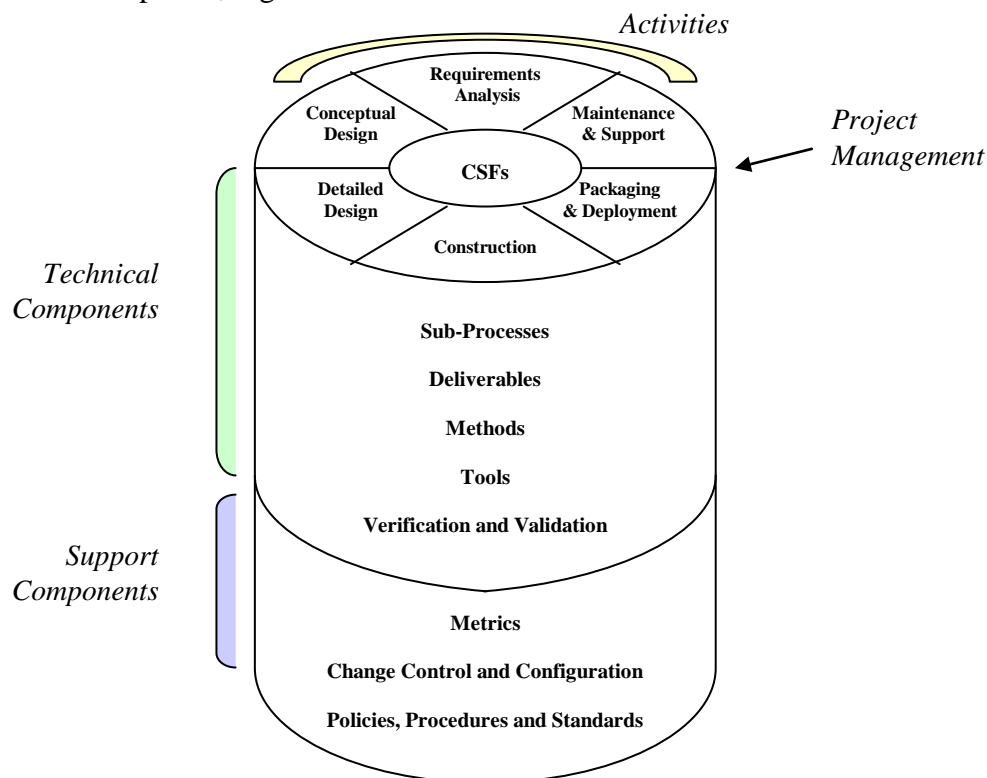
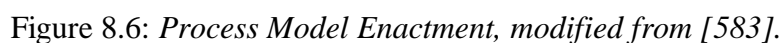


Figure 8.5: *The Meta-Lifecycle Model [593].*



The domain repository is a mechanism for defining, storing and managing the reusable assets that comprise the Business Model Template. The notion of a repository can be analogous to that of a library. The repository is aimed at providing a central place for creating, maintaining and retrieving domain assets. The repository should support the

enterprise and life-cycle activities. These activities hold and manage the information required to create, modify, evolve, execute and maintain individual Business Strategy Driven IT Systems. The domain repository should facilitate assets reuse across different IT systems, environments and domains. The repository should be properly managed, catalogued and structured such that assets are of the highest possible quality, asset identification is easy and the whole system is easily modifiable and adapts to meet changing requirements of specific domains.

CHAPTER 9

SYSTEMS ARCHITECTURE

9.1 Introduction

The purpose of this chapter is to describe the conceptual development of a Systems Architecture to provide a foundation upon which the implementation of new, re-useable, component-based systems can be founded. The transition to a process-orientated business model will require the implementation of software components and process management across business function boundaries rather than within functions. IT, in the form of communication networks, databases and integration middleware often underpin the 'architecture' of business process redesign exercises [596]. In examples such as Wal-mart [597] and Xerox [598] the role of enabling technologies was identified as an integral part of implementation success. Furthermore it is stated by Grover et al [599] that practical options in designing and implementing processes in a business change effort can either be constrained or enabled by IT infrastructure.

9.2 Systems Architecture Specification

The term architecture is used in many walks of life and can be considered to be the 'art of building'. In respect of the systems architecture described here, it can be seen to consist of a set of domain specific services, platform decisions (hardware, software, networking) and data storage facilities that support the management and flexible interoperation of software components. The suggested architecture does not presuppose that software components will be co-located. Activated components may be concrete (single location) or virtual (globally distributed). The conceptual distance, or gap, between virtual components and the underlying architecture will potentially have an impact upon expected system performance.

The proposal of this Systems Architecture is designed to combine current emerging technologies and specific collaborator requirements to offer enterprises increased flexibility, ease of application development, improved communication, interoperability and integration, of different business processes and organisations. The following list portrays a summary of combined requirements:

- ◆ Conformance to real-time (zero latency) systems principles defined by Stankovic [594].
- ◆ Provision of support for intranet, internet, and telephony [515].
- ◆ Has platform-independence [3].
- ◆ Scalability [482].
- ◆ Standards compliance [164].
- ◆ Openness and portability [164].
- ◆ Supports enterprise model enactment [3].
- ◆ Flexibly support software component configuration, operation and re-use [601]
- ◆ Provide facilities for simulation and 'what-if' scenario testing.
- ◆ Support for business intelligence, at both primitive (OLTP) and derived data (OLAP) levels.
- ◆ Proactive monitoring of the enterprise's business domain, automatically alerting enterprise management to business problems and important market information
- ◆ Encapsulates and secures enterprise knowledge and intellectual capital for visualisation and reuse.
- ◆ Incorporates active system management, configuration and security tools.
- ◆ Contains facilities for data archive, validation and consistency checking.
- ◆ Has high operational availability (i.e. 24 hours a day / 7 days a week) and quality of service.
- ◆ Can be developed and supported internal or external to the enterprise.
- ◆ Provides effective data security and can perform rapid disaster recovery.

9.3 Conceptual Systems Architecture Design

The System Architecture design provided here represents what the author considers to be an improved and more realistic definition of business needs, rather than current approaches which include CIMOSA's integrating infrastructure (IIS) [3] [164] and the notion of a 'computational infrastructure' suggested by Weston [469] [601].

Whilst the CIMOSA IIS is conceptually aimed at providing enabling technology to achieve physical and application integration, no complete CIMOSA based IIS has ever been produced [3] and its importance has been reduced by the larger industry uptake of general purpose integration techniques such as CORBA and web-based Java Beans [148]. The computational infrastructure model advocated by Weston [469] develops the business case for the deployment of integration principles,

but it does not specify in any great detail how such an approach could be technically implemented. Further comment is made that in practice it is very difficult for contemporary IT deployment to break free from tangled webs of inter-connected systems and standards that have developed over time and are not in need of replacement. Additionally, Linthicum [602] proposes that the only way in which to achieve computer system scalability is to adopt higher tiers of client/server architecture (i.e. intermediate levels of application servers between the enterprise database and the user clients). This position however can represent a trade-off, as higher scalability generally means more complexity and cost.

The design of the Systems Architecture, illustrated by Figure 9.1, results from consolidation of previous research work upon IIS and computational infrastructures, but it is also extended to contain system hardware and data storage facilities. It is believed by the research collaborators and in particular the author, that this would be an improved design methodology due to its overall approach, rather than being comprised of many individual elements.

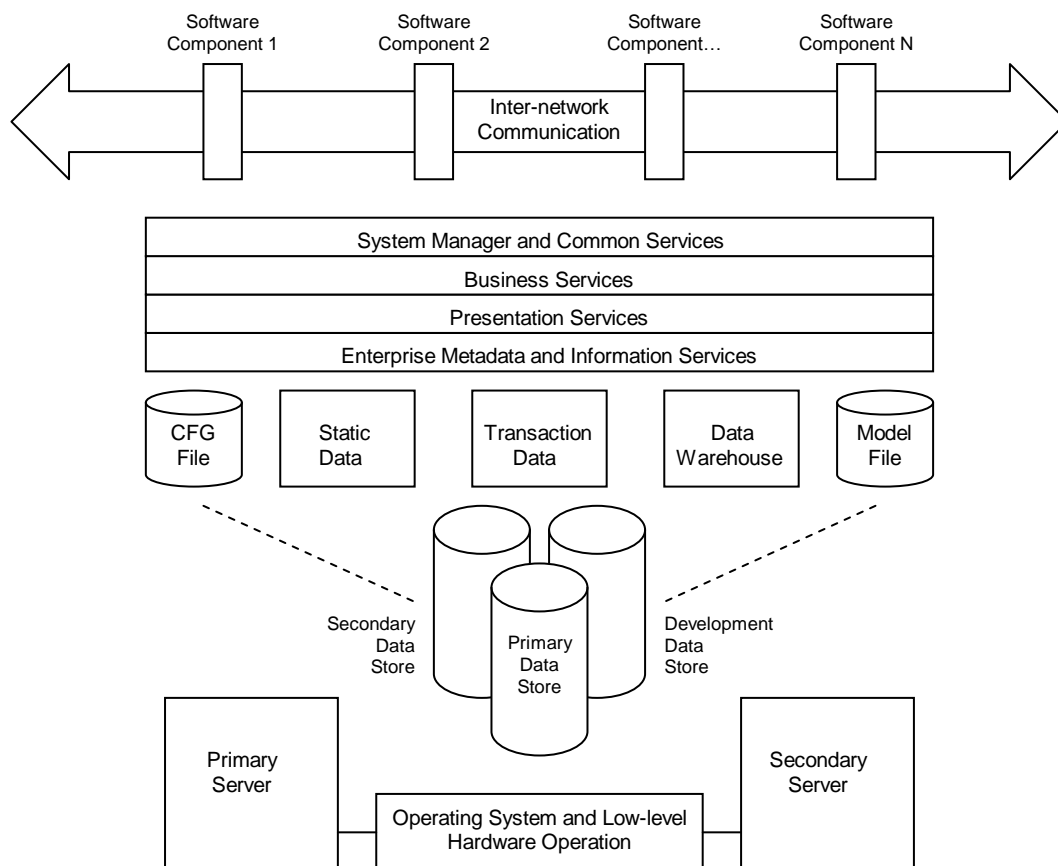


Figure 9.1: *Systems Architecture Overview.*

The design of the Systems Architecture would use the common, business, presentation and information services provided by CIMOSA [228] to:

1. Isolate the process-orientated software components from the data processing and business environment.
2. Operate system-wide and not require the software components, databases and hardware using these services to have any knowledge of their location and/or distribution.
3. Provide common protocols allowing people, machines and additional software to interact with the whole system in a uniform way.

The System Manager would be utilised to define system structure, organise process operation and system transactions, manage data integrity, together with enforcing security and counteracting any potential operational failures. Data store provision would be three fold and consist, primary (live system), secondary (a mirror of the live system to ensure availability) and development (used for software development and testing).

Data storage design would comprise three levels, static (changes infrequently), transaction (produced through the completion of process activities) and warehouse (used for any derived management reporting). To facilitate the removal of batch processes, in respect of data extraction, software components would be sufficiently configurable that they could simultaneously validate and write selected data into the warehouse, the same time as posting information to transaction data store. All data store access would be controlled through enterprise metadata and the CIMOSA information services.

Model and configuration files would be utilised to 'enact' and operationalise the whole system. The utilisation of mirrored computer servers would ensure high system availability, with shared processing to distribute load and a real-time failsafe capability in the event of an individual server failure.

It is anticipated that implementation of the design concepts could be achieved at reasonable cost and the whole solution would be capable of operation, internal or external to an SME. (i.e. operated and maintained within a datacentre environment by a third party).

9.4 Systems Architecture Application

The proposed systems architecture may be implemented in an enterprise utilising existing technologies and IT infrastructure, as its format and support requirements are comparable to those of contemporary ERP systems. In essence the newly designed architecture is similarly comprised of three integrally-linked primary elements: IT network, support software (excluding process components) and hardware, but additionally has a process rather than functional module focus, together with integration to form one coherent system.

The process of Systems Architecture implementation would consist of a top-down selection and deployment approach where the constituent parts are pre-determined by the overall choice of business domain and process-orientated software components. Within a particular business domain repository, such as ETO/MTO SMEs, a decision matrix would be provided to list the approved constituent parts that are available. Therefore, once an enterprise had made its selection of strategy, business model, business processes and associated enabling software components, it would then further select the architecture constituents required to support the effective overlay and runtime of the software components. Constituent parts could comprise of proprietary IT products or technologies already employed within the SME, e.g. Oracle's DBMS, where they had previously been approved and conformed to Systems Architecture specifications. It is recognised, though, that the selection and availability of Systems Architecture constituents would in the large be restricted by cost factors. I.e. at this moment in time it is highly unlikely that an independent SME would be able to bear the implementation cost of a global VPN alone. The application of a Systems Architecture within an SME can be viewed in Figure 9.2.

It is envisaged that Systems Architecture selection and deployment would be undertaken in a collaborative manner between internal enterprise personnel, domain repository support staff and third party solutions providers, where appropriate. Utilising, a combination of complementary and pre-approved constituents in this way it is anticipated, Systems Architecture implementation times could be kept to a period of weeks as opposed to months. It is acknowledged that substantial time and effort would be required to grow and refine Systems Architecture principles and constituents in the initial stages of Business Strategy Driven IT Systems development.

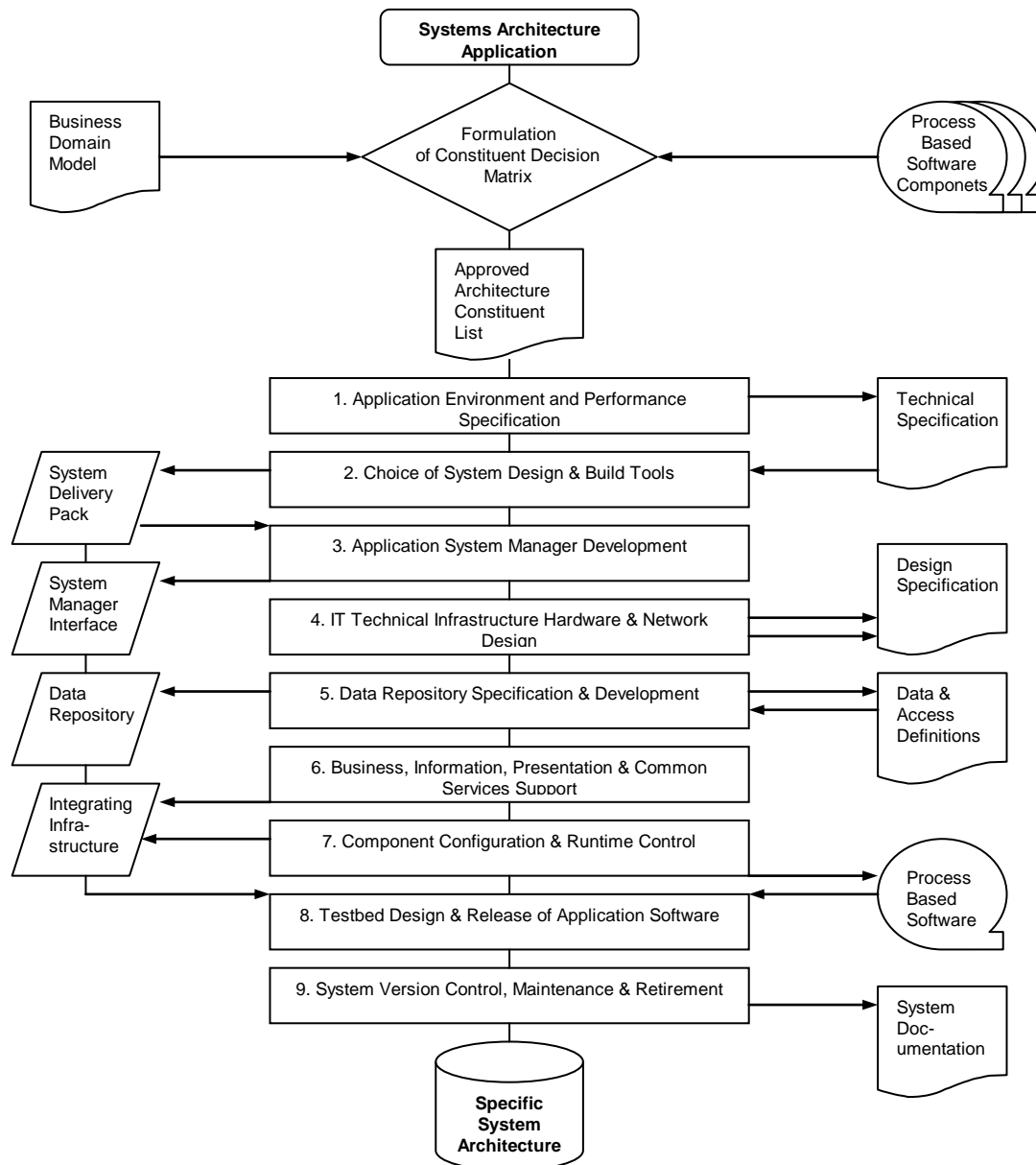


Figure 9.2: *Systems Architecture Application.*

9.5 Considerations

The complexity of integrating diverse IT systems, coupled with their evolutionary nature can make the selection and use of a single approach difficult. In today's perplexing business environment, most technologies can be both competing and complementary. Therefore, focus should be placed upon selecting a primary solution to minimise cost and support problems, such as a Business Strategy Driven IT System, but recognising that supporting roles may still be necessary in some instances (e.g. customer-enforced use of a proprietary EDI package).

CHAPTER 10

IMPLEMENTATION FRAMEWORK

10.1 Introduction

This chapter is designed to present a detailed overview of the procedure and actions required to successfully implement, a chosen Business Strategy Driven IT System within a ETO/ MTO SME. Successful manufacturing business systems require much more than just strategically aligned integrated software. They require the right people and the right support structures. The implementation framework presented here, primarily based upon the author's and collaborating enterprise experiences, aims to provide SMEs with a methodology that will ensure the effective delivery and timely achievement of implementation goals.

10.2 Framework Rational

Business system implementation failures are not uncommon and the reasons for their failure may be wide. Some typical causes are cited by the CCTA [603] as:

- Lack of co-ordination of resources and activities.
- Lack of communication with interested parties, leading to products being delivered that are not what the customer wanted.
- Poor estimation of duration and costs, leading to projects taking more time and costing more money than expected.
- Insufficient planning of resources, activities and scheduling.
- Lack of control over progress so that, projects do not reveal their exact status until too late.
- Lack of quality control, resulting in the delivery of products that are unacceptable or unusable.

Without a implementation framework or overall methodology, those who commission a project, those who manage it and those who work upon it will have different view points about how it should be planned, organised and implemented. As such the project participants will not be clear of their roles, responsibilities and authority, as a result

confusion may prevail. The utilisation of a structured approach, based upon good practice should ensure successful delivery and not failure as seen when FoxMeyer Health Corporation entered into bankruptcy due to an ERP implementation failure [540].

10.3 Implementation Framework Design

The design of the framework is loosely targeted at delivering full enterprise life-cycle coverage for Aguiar and Weston's [152] four phase approach to integrated manufacturing systems development. These phases include strategic planning, conceptual design, detailed design and implementation, together within system operation and maintenance. This high level representation was preferred by the author as it extends CIMOSA's three life-cycle phases [164] (requirements definition, design specification and implementation description) to explicitly include strategic planning activity, but it is not as complex as the seven phase life-cycle definition provided by GERA [137].

Whilst acknowledging these key principles of the life-cycle coverage, the eleven stage Implementation Framework has been developed to represent what the author considers to be more of a 'fast-track' approach to manufacturing business systems implementation. Here shorter lead-times should be achievable through the utilisation of the readily constructed Business Strategy Driven IT System modules (i.e. business models, software components and systems architecture contained within a domain repository). As such the Implementation Framework embraces principles of rapid application development defined by Martin [604] as well as incorporating elements of industrial IT project management approaches such as the CCTA's Prince2 [603] and SSA's Basis [605] methodologies. The eleven stages of the Implementation Framework can be seen below:

1. Migration Opportunity Review

A common fear of enterprises is the unknown. The initial procedure of this framework is to remove the 'fear of the unknown' and demonstrate that there is in fact a methodology for the successful implementation of Business Strategy Driven IT Systems. This would be encapsulated in a Project Mandate document. This process may include Porter's [59] five

forces and value chain, SWOT [232] analysis or Uppington and Bernus' [255] change feasibility studies.

2. Systems Assurance and Business Pre-requisite Attainment

System assurance is the process of ensuring that the individual enterprise is in a suitable position to undertake the implementation of the new manufacturing business system. This would comprise of making sure that the enterprise understands the necessary implementation steps and has budgeted sufficient time and resources to undertake the implementation. Basic business pre-requisites should also have been met, which should include:

1. Creation of a project scope document
2. Clearly defined organisational roles and responsibilities
3. Existing processes documented to gain a firm understanding of current processes
4. Definitions of strategic and operational performance measures.
5. Defined and agreed control points, with clearly documented methods for corrective actions where controls are not met.
6. Data accuracy for raw materials, work in progress, finished goods and BOMs.
7. High performance against the enterprise's production schedule.
8. The enterprise, or individual part thereof, must only operate from a single plan.
9. Responsibility for this plan must reside with a single person within the enterprise.
10. Confirmed demonstrated capacity as opposed to theoretical capacity.
11. High levels of supply chain performance

3. Project Definition and Planning

The purpose of the project definition phase is to formulate the project's strategic goals, objectives and measurements, and to develop a comprehensive definition of the new system's operation, timing and budget. The outcome of the process would be a project initiation document and an overall implementation plan.

4. Implementation Preparation and System Install

A technical assessment report would be produced for the enterprise in preparation for the installation of the enterprise's domain systems architecture. After installation the main purpose would be to educate the overall system manager and key support personnel on its use, and obtain agreement on the design of all required changes to policies, procedures and controls.

5. Particular Model Generation

This procedure would consist of the derivation of particular business process models, based upon the requisite domain repository's semi-generic enterprise models and the process related documentation, as developed within items 3, 4 and 5 of the System Assurance process.

6. Software Component Specification / Prototyping / Simulation

Based upon the particular business models developed in the previous stage, process-orientated software components would be specified and selected from the domain repository. Base components could undergo further prototyping and simulation to confirm their applicability to the enterprise in question.

7. Software Component Development and Confirmation

After software component selection has been completed, the processes would have to be configured to exactly meet the enterprise's systems architecture, as well as any specific management reporting or operational criteria. Once this development process was complete the software component would have to be formally released to the live business system, documented and signed off.

8. System Integrity and Stress Checking

In the initial stages of Business Strategy Driven IT Systems development, or through major modification, to either software components or systems architecture, the whole system would have to undergo system integrity and stress checking, to ensure the effective performance of the developed system. This could be undertaken utilising packaged software testing tools such as Compuware's QA Run product and once complete would be signed off by the enterprise's system manager.

9. Implementation and Training

The purpose of this phase is to ensure the readiness of the enterprise's procedures, personnel and data prior to cut-over, convert static and variable data, and begin operation of the new system. Detailed user-level training and system pilots would have to be undertaken. For most implementations, this would be performed in time-phased fashion, which include schedule, operations, personnel and data reviews. A final readiness review recommendation would have to be approved before the system went live.

10. New System Operation, Support and Service Level Definition

The purpose of this activity is to release the system for live operation and ensure the completeness of all aspects of the enterprise's organisation, policies, procedures and controls necessary for the effective support of the new system. It would include defined service levels and change control procedures.

11. Post Implementation Review and Audit

This procedure would be undertaken to assess the success of the whole system implementation and would generally take place after around 3 months of live systems operation. This would allow a reasonable period of system stability to have been achieved. The review process would require a set of criteria. These have to include what the systems do and whether they meet their original specifications. Preece [606] defines systems acceptability as being composed of four individual criteria:

- Technically acceptable - The knowledge contained within the systems must be sufficiently sound and complete for operational use.
- Ergonomically acceptable - The user interfaces must be engineered to meet both the needs of the domain and the interaction appropriate to the users.
- Organisationally acceptable - The systems should be compatible within the organisation, which may mean changing the systems or the existing procedures.
- Ethically acceptable - It is crucial, particularly for legal reasons, to establish where responsibility lies for the systems recommendations being implemented.

10.4 Concluding Remarks

In conclusion the successful implementation of manufacturing business systems can be closely coupled to overcoming people's resistance to change. People's resistance to change can make it very necessary to present, coach, train and pilot simple projects first. It can be equally important to consider the fact that many people may have worked in the same job for a number of years while the managers have been in their positions for less. Therefore enterprise management has to demonstrate truth and commitment and show that they can achieve success.

Strategically managers will sometimes try to introduce organisational changes quickly, in a matter of days or weeks, perhaps before people realise what has happened. At other times, they proceed slowly; change efforts have taken years before they are successfully completed. Managers sometimes involve no one but themselves in the planning and execution of change; at other times, they involve many people, perhaps everyone affected by the change. In managing change, the enterprise managers will be confronted with many choices. They must decide (1) How much change to try and accomplish, (2) How much effort will be directed at problem solving versus developmental change and (3) What specific strategy and tactics to use.

The difficulties inherent in making these choices are the number of options possible at any one instance. Enterprise managers may use a number of tactics to deal with resistance to change. These tactics and their application can be seen in Table 10.1.

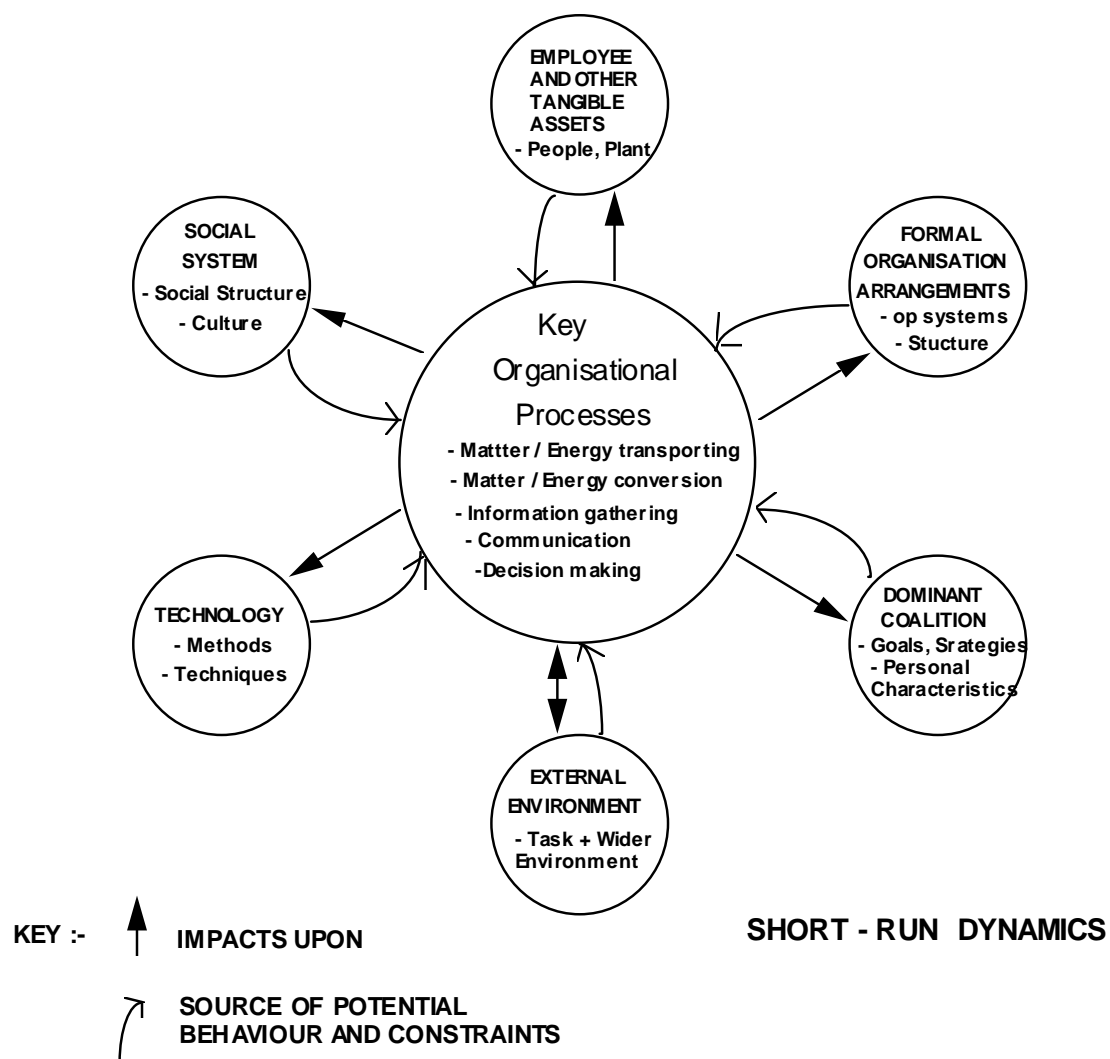
Tactic	Best for :-	Advantages	Drawbacks
Education/ Communication	Resistance based on lack of information or inaccurate information and analysis.	Once persuaded, people will often help with implementing the change.	Can be very time consuming if large numbers of people are involved.
Participation	Situations in which initiators do not have all the information needed to design the change and where others have considerable power to resist.	People who participate will be committed to implementing change. Any relevant information they have will be integrated into the change plan.	Can be time consuming. Participants could design an inappropriate change.
Facilitation and support	Dealing with people who are resisting because of adjustment problems.	No other tactic works as well with adjustment problems.	Can be time consuming, expensive and still fail.
Negotiation	Situations where someone or some group will lose in a change and where they have considerable power to resist	Sometimes it is an easy way to avoid major resistance.	Can be too expensive in many cases. Can alert others to negotiate for compliance.
Co-optation	Specific situations where the other tactics are too expensive or are not feasible.	Can help generate support for implementing a change (but less than participation).	Can create problems if people recognise the co-optation.
Manipulation	Situations where other tactics will not work or are too expensive.	Can be a quick and inexpensive solution to resistance problems.	Costs initiators some credibility. Can lead to future problems.
Coercion	When speed is essential and the change initiators possess considerable power.	Speed. Can overcome any kind of resistance.	Risky. Can leave people angry with the initiators.

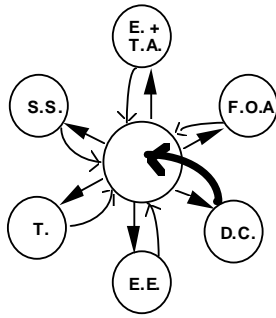
Table 10.1: *Tactics for Dealing with Change, Schlesinger et al [97].*

The implementation of a Business Strategy Driven IT System to support the dynamics of global business is a challenging and costly process. Rather than attempting to force fit a manufacturing business system to a set of business requirements, this model-driven approach requires cross-functional process orientation. The thesis concepts are driven by the business opportunity of global development, reengineering and the need to provide enabling solutions that are built to a common standard, integrated, transportable and scaleable. Emphasis is on optimising technology and eliminating redundant systems, non-standard data and unnecessary layers of organisation and personnel. Using this IT Route Map approach, enterprise management can define the

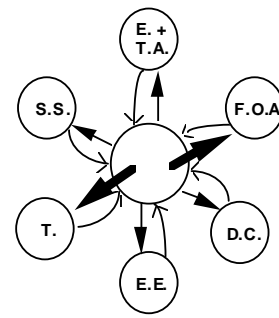
strategic business, process and resource priorities that should guide the future development of the enterprise.

Despite the fact that the capital costs of IT systems are falling rapidly, it is still the case that it represents a large investment for any enterprise to make. The optimum place to make such a change towards the end goal is at the edge of proven practice; not everyone is using the strategy or technology and it has minimum risk with maximum return. It is difficult to conceptualise the change process and to help understand the IT Route Map change path the application of Kotter's [101] organisational schema can be used. The cause effect dynamics of the introduction of a global system into an enterprise can be seen in Figure 10.1. These impacts and constraints can be viewed as key factors in shaping the short run system dynamics, generally over a period of days to months.

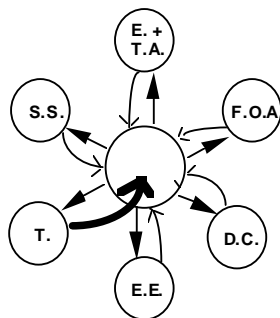




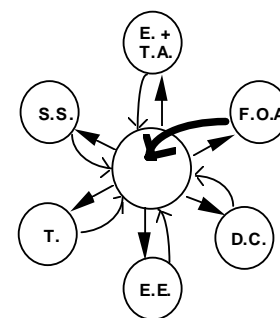
1. The introduction of a globally focused manufacturing business system into an enterprise will take place when key individuals, such as the general manager and directors develop dissatisfaction with the status quo.



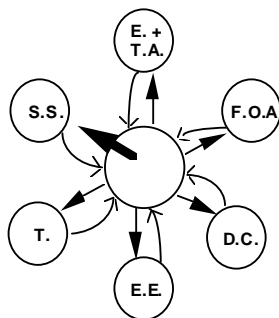
2. The decision to proceed with the introduction of a new system creates the need for analysis and evaluation of the present enterprise systems. Technology has to be a big issue, formal techniques, methods and an implementation plan have to be found.



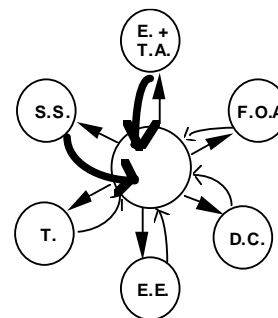
3. Availability and detailed descriptions of suitable technology dictate the way in which the new system will be implemented. This will be on the basis of financial cost, performance and maintainability.



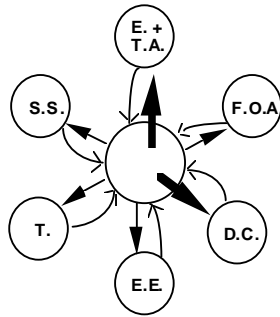
4. The vision of the future state, the operating systems and structure, can present the enterprise with a strategic goal. The vision originates from analysis and observation and has been crafted through extensive discussions.



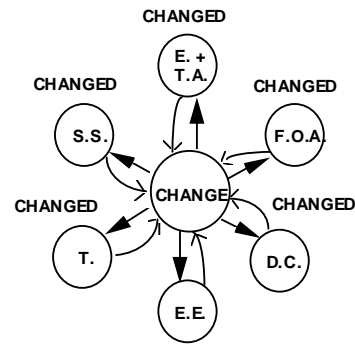
5. The model for change will affect the social structure in terms of the environment, a tightening control of individual behaviour, an increase in enterprise communication, and a shift from functional to process-orientated structures. Shift patterns and job content may also change.



6. The changes in the social system needed by the process-orientation may not be fully enforced due to human resistance. This may be due to fear, misunderstanding and a lack of trust. The physical layout of the plants and the skills of the workforce define the speed of transition, new buildings may have to be built and staff re-trained.



7. New equipment may be introduced and the plants will be re-structured. The workforce may undergo a lowering in the levels of unskilled and supervisors and a slight rise in middle management, this would lead to a decline in the spans of control.



8. The system re-stabilises with the states of six of the elements changed.

Figure 10.1: *Organisational Dynamics.*

Over the past 100 years many enterprises have tried to remake themselves into significantly better competitors. They have included varying sizes of enterprise such as Ford [107] and Tritex [13]. These efforts have gone under many banners: total quality management, reengineering, right sizing, restructuring, cultural change and turnaround. But, in almost every case, the basic goal has been the same: to make fundamental changes in how business is conducted in order to help cope with a new, more challenging market environment.

A few of these endeavours have been very successful and others have ended in complete failures, but most fall somewhere in between, with a distinct tilt towards the lower end of the scale [98]. The lessons that can be drawn from the many change programmes are interesting and should be relevant to any enterprise's future in the increasingly competitive business environment. Of these lessons there are a whole array of individual maxims proposed by different people but the eight steps for transforming your organisation developed by Kotter [97] could be seen to be the most appropriate in this respect.

1. Establishing a Sense of Urgency

Examining market and competitive realities.

Identifying and discussing crises, potential crises, or major opportunities.

2. Forming a Powerful Guiding Coalition

Assembling a group with enough power to lead the change effort.

Encouraging the group to work together as a team.

3. Creating a Vision

Creating a vision to help direct the change effort.

Developing Strategies for achieving that vision.

4. Communicating the Vision

Using every vehicle possible to communicate the new vision and strategies.

Teaching new behaviours by the example of guiding coalition.

5. Empowering Others to Act on the Vision

Getting rid of obstacles to change.

Changing systems or structures that seriously undermine the vision.

Encouraging risk taking and non-traditional ideas, activities and actions.

6. Planning for and Creating Short-Term Wins

Planning for visible performance improvements.

Creating those improvements.

Recognising and rewarding employees involved in the improvements.

7. Consolidating Improvements and Producing Still More Change

Using increased credibility to change systems, structures and policies that do not fit the vision.

Hiring, promoting and developing employees who can implement the vision.

Reinvigorating the process with new projects, themes and change agents.

8. Institutionalising New Approaches

Articulating the connections between the new behaviours and corporate success.

Developing the means to ensure leadership development and succession.

CHAPTER 11

CASE STUDY IMPLEMENTATION

11.1 Introduction

The purpose of this chapter is to assess the applicability of Business Strategy Driven IT Systems concepts within the ETO/MTO industrial domain, through the implementation of IT Route Map procedures at the premises of a collaborating company. The chapter describes the combination of business strategy and IT within a manufacturing enterprise to support corporate M&A activities and presents an evaluation of the overall thesis methodology performance.

11.2 Enterprise Background

Vesuvius Limited is considered by many to be the world leader in the development, manufacturing and marketing of high performance speciality refractory products and flow control systems for industrial applications. Refractory products control, protect and monitor the flow of liquid metal in the continuous casting process. Vesuvius is also a leading manufacturer of refractory lining materials for iron and steel making and is one of the world's largest refractory enterprises, able to offer full 'turn-key' solutions. These solutions include refractory design, supply, installation and field service to its global customers across a wide range of industries, including iron, steel and glass-making, as well as a comprehensive range of foundry and industrial products.

As the Ceramics arm of the UK parent Cookson Group, who have a turnover in excess of \$2.0 billion, Vesuvius is comprised of individual businesses, factories and sales offices that operate in 35 countries world-wide. All of which are dedicated to supplying customers with technical, engineering and process systems support, in many instances through teams permanently based at customers' facilities.

In the early part of 1999, Cookson acquired in full, Premier Refractories Limited for a fee of £252 million. Premier was a manufacturer and supplier of value added specialist refractory products, services and systems to the steel, glass, aluminium and cement industries. Premier had an annual turnover of around £300 million and consisted of 22 manufacturing sites and 3,500 employees based in the UK, North

America, Belgium and France. The acquisition and merger of the Premier business into Vesuvius would allow the combined enterprise to offer a more comprehensive range of products and services to customers world-wide. The resulting business would have annual projected sales of around £700 million with over 70 manufacturing locations strategically positioned to serve customers globally and employ over 8,000 people. It was anticipated that to derive synergies between the UK operating companies of Vesuvius and Premier substantial rationalisation would have to be undertaken across the combined UK based operations.

In mid 1999, shortly after the thesis author had joined Vesuvius (UK) Ltd as an IT Project Manager, a high-level executive steering committee was in the final stages of planning the integration of Premier and Vesuvius. The committee, with the assistance of the consultancy firm McKinsey and Company, had analysed various business re-organisation strategies and scenarios with the outcome that an approved 2 phase (phase 1 - year 2000 to 2002 and phase 2 - 2002 onwards) integration plan would be adopted. This plan, in relation to the UK operations of Premier and Vesuvius, would consist of rationalising the number of administrative offices, technical centres and manufacturing sites within the UK and 'ring-fencing' individual product operations, within manufacturing sites, to enable flexibility for any potential future site re-locations. The manufacturing restructuring financials are presented in Figure 11.1.

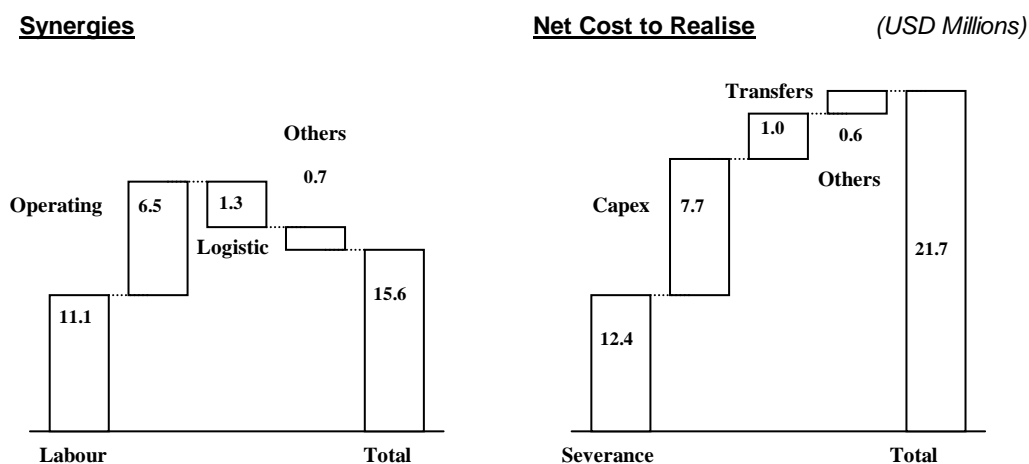


Figure 11.1: *Manufacturing Restructuring Financials.*

Furthermore, to act as an operational foundation for the enlarged enterprise, the management of Vesuvius had agreed to undertake project WAVE (World-wide

Application for Vesuvius Excellence). The project involved the restructuring of administrative functions in combination with the implementation of JD Edwards OneWorld ERP software. The objective of the implementation was to support a business structure, which would provide the greater centralization of high-volume, transaction intensive business processes. This was to be done with the intent of creating efficiencies and economies of scale in these areas and enabling customer service and manufacturing operations to maintain focus on the customer and products. The WAVE project goals were listed as:

- ❑ To provide improved visibility and accessibility of operating information to management.
- ❑ To facilitate the integration of Vesuvius and Premier, as well as that of future acquisitions.
- ❑ To provide a technology solution that could be most effectively supported and grown over the next 5-10 years.

11.3 Purpose and Scope

In the late summer of 1999, after more detailed strategic planning and negotiation with local government agencies had been undertaken, a capital expenditure voucher (CAPEX) for the value of £4.3 million was approved to implement what was to be colloquially known as the 'Hefner' project (A reference by one of the primary equipment suppliers to 'Hugh', one of the senior managers who was co-ordinating the project). The project was announced in October 1999 and comprised the following main items:

1. Closure of the Manuel (LW) and Kingscliffe (KC) locations with transfer of production operations to Chesterfield (CF) and other Vesuvius manufacturing sites.
2. Substantial re-development and expansion of the CF manufacturing site.
3. The integration of the UK's management, sales, accounts, administrative and technical operations into new purpose built offices or 'Service Centre' on a business park at Barlborough (BB).

The initial phase of the project would consist of bringing together a project steering committee (of which the author was to be the IT lead) customer briefings, internal project communications and inventory planning. The completion date of the Hefner project was targeted at the end of May 2001. The overall business structure envisaged

can be seen in Figure 11.2. Vesuvius provide product support through around 20 globally distributed 'Product Lines'. Product Lines consist of a collection of technical specialists, costing engineers and sales support personnel who have overall authority for the administration, design, manufacturing location and pricing of Vesuvius products world-wide

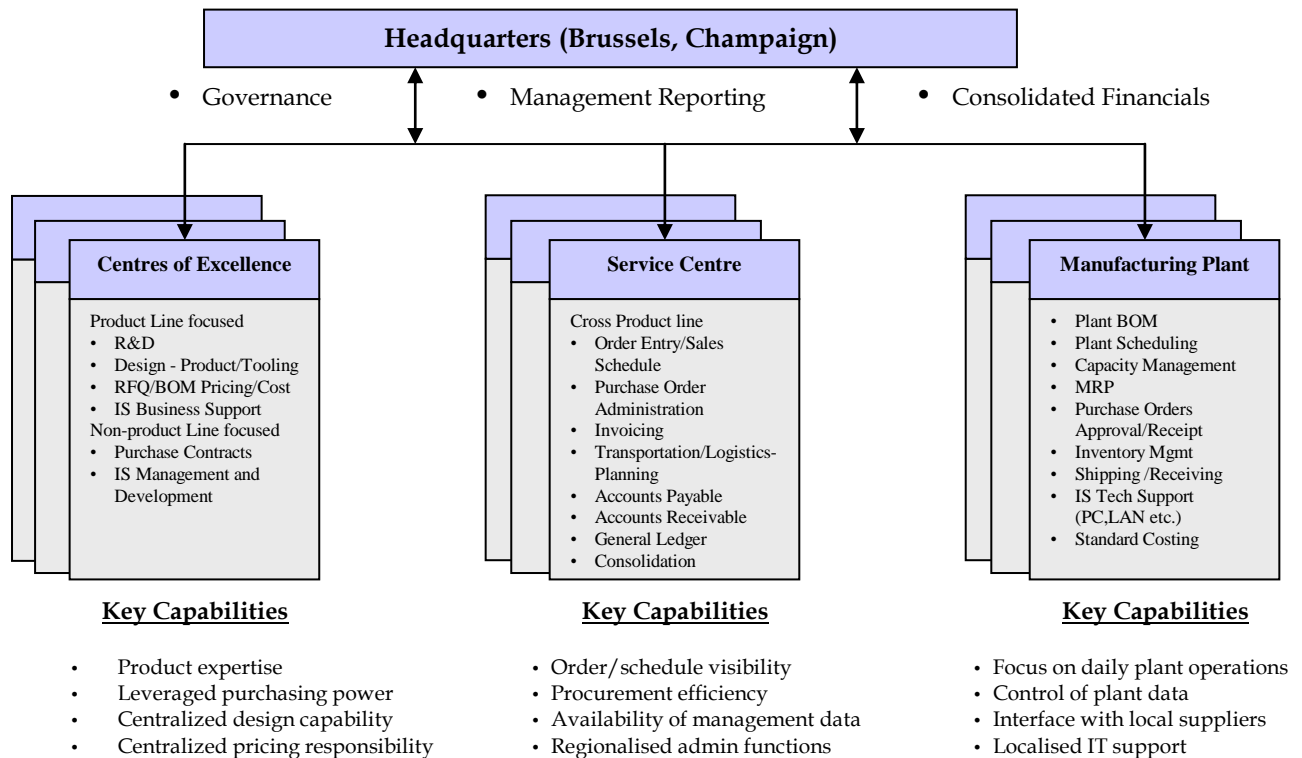


Figure 11.2: Target Business Structure.

11.4 Project Overview

The overall project exhibited a high degree of complexity and uncertainty. It consisted of many inter-linked and interdependent project phases, the involvement of nearly 500 employees between six main sites, the design and installation of a new £1.2 million computerised powder batching plant, the relocation of large capital equipment and the transfer of product and inventory, together with the integration of many disparate computer systems. All of which had to be undertaken in a time-frame of around 9 months from start to finish, to be ready to start the WAVE implementation towards the latter part of 2001.

Shortly after the project had been announced, the project steering committee was formed. It was chaired by the UK Finance Director and consisted of around 12

senior executives and managers from all of the business functions impacted by the project. Whilst the project committee planned to meet every two weeks, not all members were required to attend each meeting. The steering committee structure can be seen in Figure 11.3.

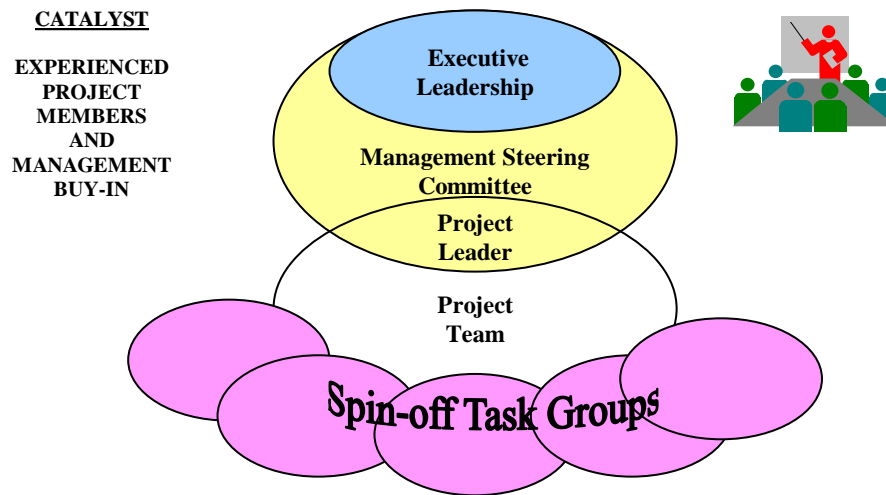


Figure 11.3: *Project Management Structure.*

The central theme of the overall project was centred upon the re-development of the CF site into a world class centre of excellence for the manufacture of monolithic and precast products. An overview of the project plan can be seen in Table 11.1. It was envisaged that both products and employees would be relocated to CF from KC and LW to create a much larger manufacturing facility that would be capable of achieving an annual turnover of £70 million. This enlarged operation would be enabled by (1) the re-vitalisation of the existing control functions and production facilities (e.g. dry powder, precast sealbind and pitch impregnation product groups) and (2) the design and installation of a new computer integrated batch plant for the weighing, mixing and packaging of powdered (monolithic) products.

The overall project plan and budget was maintained by the Project Leader in Microsoft Excel software, so as to ensure the widest possible accessibility for the project participants, and encompassed a generally, sequential approach whereby the project team would complete one phase before moving onto the next. This was necessary to provide focus and was to some degree enforced by limitations in skilled

personnel due to reductions in employee numbers at the KC and LW sites and a restriction on recruitment as directed by the corporate board to maintain low costs. Individual project participants had high autonomy for their own separate areas.

Phase	Date (M/Y)	Description
Transfer Foundry Resale Products Warehousing from CF to BW	11/99	Relocation of a relatively small sized (2500 cubic metres) warehousing facility, resale products and administrative support. This was required to release space within the CF site for the batch plant installation.
Transfer Richards Mill from KC to BW	12/99	Milling plant disassembly, re-location, re-engineering and installation, together with inventory building and a transfer of administrative support. Richards Mill products were considered to be complementary to those already manufactured within BW.
CF New Building Construction	12/99	The whole CF site was planned to undergo massive transformation. A whole new main building was constructed for the batch plant, two supplementary facilities were built for mixing and precast manufacture, quality laboratory were extended, and a new weighbridge and access road were installed
Supply of Batch Plant to CF	03/01	The batch plant was supplied and installed by a Belgium company sub-contractor and comprised five independent powder dispensing facilities, a 2 Tonne tote bin transfer line, a control office, together with bin filling and emptying stations.
Dry Powder Operation at CF	03/01	The computerisation and improved control of the facility, comprising of two milling, mixing and packaging plants used to produce dry powders in bags ranging from 4 KGs to 2 Tonnes.
Sealbind Operation at CF	04/01	The computerisation and improved control of the facility comprising of mixing, rolling, firing and packaging facilities used to produce gaskets and seals from cup size up to around 1m in diameter.
Precast Operation at CF	05/01	The computerisation and improved control of the facility comprising of mixing, moulding, firing and packaging facilities used to nozzles and blocks. Introduction of additional products from LW
Transfer of Mixers from KC to CF	05/01	The plant disassembly, re-location, re-engineering and installation, of three mixing plants, together with inventory building and a transfer of administrative support. These would be fed with raw materials tote bins delivered from the new batch plant.
Batch Plant Operation at CF	05/01	Completion of the new batching plant and acceptance testing of its computer based control system, ready to start live production. Introduction of raw materials and products from KC and LW. Serve customers from new CF production facilities.
Office Move to BB	06/01	Re-location of around 120 employees from CF and other Vesuvius UK sites to new offices and technical workshops based at BB. Involved, a change to the company's UK registered address, transfer of office equipment and the installation of telephone and computer networking facilities. The building had been previously purpose built and would be occupied under a lease agreement.

Table 11.1: *Project Plan Summary.*

To understand the background and rational of the project further a summary of the manufacturing sites involved is presented in Table 11.2. Additional explanation of product groups is provided in Table 11.3.

Location	Company (Employees)	Product Groups	Summary
Chesterfield (CF)	Vesuvius (200 Before) (100 After)	Dry Powder, Sealbind, Pitch Impregnation, Precast Monolithics, Foundry.	The CF location consisted of three business functions: UK head office (sales, administration, finance, purchasing and IT), Monolithics Product Line office and local site manufacturing. Over recent months, through the integration planning process, the future of the site had been unclear and little investment effort, in terms of developing the manufacturing plant and employees, had been made. It did though hold the key strategic pitch impregnation facilities, was located within a government special assistance area and had good facilities in terms of buildings and logistics access.
Bawtry (BW)	Premier (100)	Aluminium, Monolithics.	This could be considered to be a standalone site that produced graphite-based products for the aluminium industry. It had recently undergone a massive investment process to introduce state of the art machining and firing equipment to improve the production of graphite cathodes.
Kingscliffe (KC)	Vesuvius (90)	Monolithics	The site contained very experienced employees and strategically important milling and mixing equipment for the production of monolithic products. The site infrastructure was considered old and expansion may have been unrealistic due to local restrictions on traffic increases.
Manual (LW)	Premier (200)	Monolithics.	Complementary products to KC and CF were manufactured at the site. It had not undergone any major investment in recent years, but did have an experienced work force.
Barlborough (BB)	Combined (140 - when relocated)	N/A	This new location would consist of two office buildings. One, a new UK head office with facilities for centralised functions (sales, administration, finance, purchasing and IT) and the Monolithics Product Line, together with the second, a new Technical Centre to support the combined enterprise's R&D efforts.

Table 11.2: *Location Summaries.*

Product Group	Type	Volume	Variety	Process	Description
Dry Powder	MTO	Medium	Medium	Batch	Mixed powder material used to aid the removal of impurities from steel production processes.
Sealbind	ETO / MTO	Low	High	Discrete	Chemically bonded plastic gaskets and seals.
Pitch Impregnation	MTO	Medium	Medium	Discrete	High-pressure impregnation of slide gate plates and inserts with pitch.
Precast	ETO / MTO	Low	High	Discrete	Well Blocks, IPV Nozzles, Purge Plugs, Oxygen Lances and Gas Diffusers.
Monolithics	MTO	Medium	Medium	Batch	Castables, Graphitic Rammings, Taphole Clay, Silica Gunning, both wet and dry mixes.
Foundry Resale	RESALE	Low	High	Discrete	Finished foundry products imported from other Vesuvius sites and held on stock for rapid delivery.
Aluminium	ETO	Low	High	Discrete	Graphite cathodes for use in the aluminium smelting process.

Table 11.3: *Product Group Descriptions.*

The scope of the project was considered to be exceptionally wide with an ambitious time-scale. Vesuvius as a whole was facing a severe down-turn in its markets, due to increased competition, customer moves to sourcing steel from cheaper manufacturers

located in countries such as Poland and China, together with the planned closure of several UK steel mills by Corus, one of Vesuvius' largest UK and European customers.

The success of the Hefner project, would offer the UK operation of Vesuvius longer term viability and assist the Cookson Group and its shareholders in realising the planned benefit to be gained from the Premier M&A process.

11.5 Batch Plant Design

The batch plant was designed and introduced to semi-automate the rapid weighing and preparation of powdered raw material, such as silicates and cements. The system was primarily based upon the utilisation of 2 Tonne capacity tote bins, an underground roller/lift/conveyer transfer mechanism, 5 integrated storage, weighing and dispensing stations, together with a SCADA based production control system. An overview of the system can be seen in Figure 11.4.

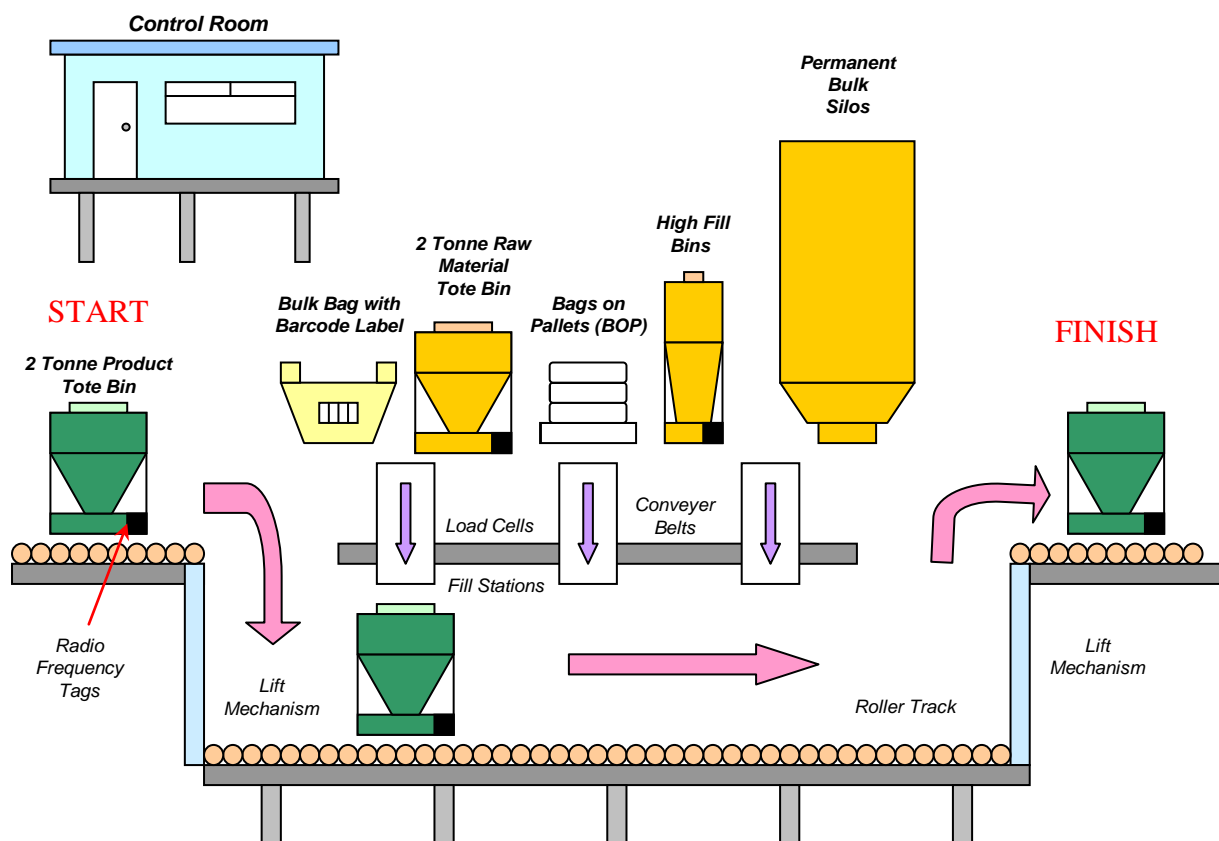


Figure 11.4: *Batch Plant Overview.*

- ◆ *Separate storage types are used to accommodate different material characteristics and flow types.*

Both tote and high fill bins are of steel construction with manual fitting lids on the top and valve release mechanisms at the bottom. Bulk bags are of nylon mesh construction with lift handles on the top and rope tie releases at the bottom. All three require handling by Fork Lift Trucks (FLT's). BOP refers to standard paper and plastic sacks containing raw material, which are located upon wooden/plastic pallets. Whilst the pallets are loaded onto the plant using FLT's, the actual bags require hand-operable vacuum lifts to comply with health and safety legislation. Bulk silos, are maintained, external to the main building, by road tankers who 'blow' powdered material through an entry channel to fill the silos from the top.

The whole production operation would be controlled through the utilisation of a SCADA based control system, load cells, and actuators, together with Radio Frequency (RF) tags and RF read/write heads. The whole control system was to be designed and supplied by the plant manufacturer. The RF devices would enable the storage of small amounts of digital data (up to 8 MB in this instance) to be stored in the tags without a fixed connection. Whilst most of the RF read/write heads would be controlled by the plant's SCADA control system, a series of independent ones would also be deployed to facilitate interfacing with Vesuvius manufacturing business system. In these instances, the RF read/write head would be connected to a PC through a RS232 cable and serial connection and would be capable of data transmission up to distances of around 2 cm.

The operation of the plant would be undertaken in several stages. An empty tote bin would first be placed upon the start position where by a production recipe or BOM would be written to the RF tag upon the bin, by Vesuvius' manufacturing business system. The bin would proceed along the roller track until it was in position with the lift mechanism, here the batch plant control system would read the BOM and decide which stations the bin would have to visit, together with what material and how much would have to be dispensed. After descending into the tunnel, the bin would pass through the filling stations and receive the necessary raw materials, in the desired quantity, before exiting via the secondary lift. Here after completion of the bin fill process, the bin weight would be validated before the batch plant control system inventory would be down-dated and the details of the actual products within the bin written back to the RF tag.

After moving to the finish position upon the roller track, the RF tag would then be read by the Vesuvius manufacturing business system, to consume raw material inventory by actual figures and move the final product's production on by one stage. The composition of the plant can be seen in Table 11.4, and the supplier guaranteed bin throughput was stated at one tote bin (2 Tonne capacity) every six minutes. This equates to potentially 480 Tonnes of production within a 24-hour period and logistical replenishment and delivery movements of over 1000 Tonnes a day, (including the additional manufacturing operations upon the site). This amount of site logistical actively combined with high variability of FLT movement within the factory may result in the management, maintenance and scheduling of FLT's potentially being a very complex issue.

Plant Locations	Plant No.	Additional No.	Capacity Each.	Manual / Auto	Control
Finished Goods Tote Bins	1	50	2 Tonnes	A	Finished Goods RF Tag and Load Cells
Bulk Bags	12	N/A	1 or 2 Tonnes	A	Supplier Barcode and Load Cells
Raw Material Tote Bins	20	50	2 Tonnes	A	Raw Material RF Tag and Load Cells
Pallets (BOP)	5	N/A	1 Tonne	M / A	Manual Dispense / Auto Weighing via Load Cells
High Fill Bins	25	25	1 Tonne	A	Raw Material RF Tag and Load Cells
Bulk Silos	11	N/A	25 Tonnes	A	Load Cells

Table 11.4: *Batch Plant Composition.*

Associated with the main batching plant are a number of supplementary pieces of equipment and mixers that will be used to facilitate the efficient transfer of raw materials into saleable finished goods. These are listed below:

- ❑ A tote bin filling station, with capacity for three individual bins.
- ❑ A tote bin emptying station with capacity for two individual bins.
- ❑ A tumble blender to rotate-mix material contained within full tote bins.
- ❑ Three product mixers with associated packaging facilities. Two located in the main warehouse, one located in separate building on-site to ensure no cross contamination of products.

- High Fill Bins**

Bulk Silos

Tunnel Exit

BOP Station

Control Room

Mixers

Kanban Area

Bin Fill Station

Bin Empty Station

Bulk Bags

AGING MATERIALS

Tunnel Entry

Raw Material Bins

Packaging

Tumble Blender

Legend:

 - FINISHED PRODUCT (Green square)
 - RAW MATERIALS (Yellow square)
 - PALLET (Orange square)

Category	TO BE DETERMINED	TOTAL
FINISHED PRODUCT	10	10
RAW MATERIALS	10	10
PALLET	10	10

Figure 11.5: *Batch Plant Factory Layout.*

Each of these pieces of equipment would be fitted with RF tag read/write heads to enable production transactions to be seamlessly undertaken on Vesuvius' manufacturing business system, e.g. automatically write the material contents of a bin, once filled, onto the bin's RF tag or down-date tote-bin held stock as material is consumed or packed. Independent, of the plant control and enterprise manufacturing business system, would be portable RF tag readers to enable the tracking of bins throughout the factory. A layout of the main batch plant factory is provided in Figure 11.5.

11.6IT Background

The strategic deployment of IT within the two individual businesses demonstrated a contrast. Whilst the Premier business had adopted, what is described by Remenyi [440] as a 'monopoly' approach, where a centrally managed service is deployed to meet end-user demand within reasonable cost, Vesuvius had adopted what could be seen as a 'scarce resource' approach [440] where there exists very tight financial controls. The types of systems and personnel within each of the businesses also varied greatly. Premier operated a centralised bespoke manufacturing package, run upon an externally managed (Datacentre) IBM AS400 computer, where as Vesuvius had developed its own local MRP solutions based upon a Novell operating system architecture. Both systems were old (> 15 years) and poorly supported. An approach comparison can be seen in Table 11.5.

Deployment	Feature	Premier UK	Vesuvius UK
Strategy	IT Management	Direct report to Finance	Direct report to Corporate IT
	Objective	Stable, low-risk, generalised IT solution, operations support	Internally developed solution to closely meet business need at low cost
	Formal Planning	No	Yes
	Service Levels	For external Datacentre support	Yes
	Budgetary Control	Yes	Yes
	IT Perception	Low	Low
	Planned Availability	9-5 Mon-Sat	9-5 Mon-Sat
Organisation	Sites No.	5	5
	IT Employee No.	5	12
	User No.	120	250
	Co-ordination	Central	Central and Local

TABLE CONTINUED OVER

IT	Platforms	IBM AS400, Microsoft NT	Novell, NT, IBM Unix (SUN)
	Business Systems	Centralised bespoke development Sales, Purchasing, Inventory and Accounts (AS400 based, RPG400 programming and IBM DB2 database)	Local site Vicsys (Vesuvius Integrated Control System). Client Server System developed in house Integrated MRP, Sales, Purchasing, Manufacturing, Inventory Control (Novell based, Clipper programming and Pervasive Btrieve SQL database)
	Accounting	Through Premier Business System	SUN Financial Package
	Helpdesk	Via Datacentre	Yes
	E-mail / Workflow	Lotus E-mail	Lotus Notes
	Office Applications	Lotus Office	Microsoft Office
	Reporting Tools	AS400 Query	Crystal Reports / Cognos BI
	Networking	LAN / WAN	LAN / WAN / VPN
	Internet / EC	No	Yes, Corporate Web site
	Remote Access	Via IBM Dialup Client	Via Citrix Remote Access Servers
	Development	External	In house (Clipper, Delphi & Notes)
Manufacturing	CAD	YES, AutoCAD	YES, AutoCAD
	Costing	YES	YES
	BOMs	NO	YES
	Routing	NO	YES
	Inventory	YES	YES
	Re-order Point Control	YES	YES
	MRP	NO	YES
	Production Scheduling	NO	YES
	SPC	NO	YES
	Barcoding	NO	YES
	SCADA	NO	YES
	NC-CNC	NO	YES
	Robotics	YES	YES

Table 11.5: *IT Approach Comparison.*

The status of the IT infrastructure and business systems development within the CF manufacturing site was considered to be very limited. Whilst the UK Central Office and Monolithics Product Line were well supported with IT (i.e. access to other remote manufacturing sites to place sales orders and a selection of their own systems, such as SUN financials and a Lotus Notes based product and quotation database) the local CF manufacturing function had previously undertaken only a piecemeal implementation of the main Vesuvius manufacturing business system - Vicsys. This Vicsys installation comprised a shared server with a partial Vicsys system software installation and was being utilised for basic sales, purchasing and inventory management support. All other functions such as shop floor control, production planning and quality control were

being undertaken upon paper-based systems. A topology of the corporate systems used in relation to the Hefner project can be seen in Figure 11.6.

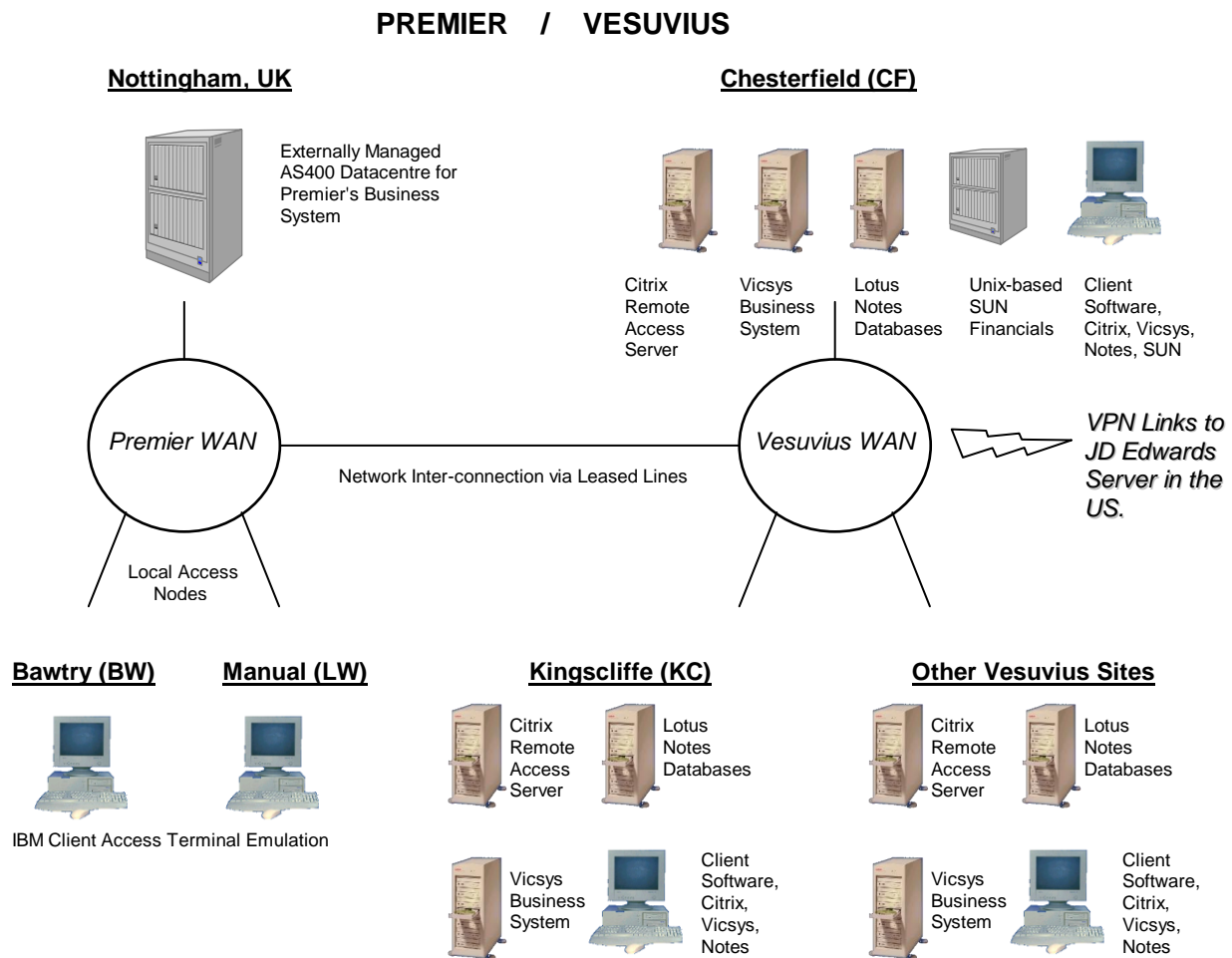


Figure 11.6: *Corporate IT Overview.*

The specification and selection of a manufacturing business system for the enlarged CF site was the main dilemma faced by the Hefner project team. The Premier AS400 system did not contain the necessary functionality, required for the new batch plant (i.e. integrated production planning and control) and the Vicsys system existent within CF was not fully installed for manufacturing support.

Additionally, it was envisaged that when the UK Head-office and Monolithics Product Line employees and systems were re-located to the new Barlborough offices, the local CF manufacturing function would be further exposed. Especially in its ability to operate effectively, due to its part-reliance upon and sharing of some of the central functions, such as secretarial, accounting and purchasing support.

Despite the two individual IT departments being quickly integrated, IT staff still continued to support the business systems that they were familiar with and little skills cross-over was achieved. It was anticipated that this would not be required until the JD Edwards implementation started within the UK.

11.7 IT Objectives

The IT related objectives for the Hefner project could be seen as:

- ❑ The provision of a single business system solution for the CF site.
- ❑ Enable the separation of IT Service Centre and Product Line functions from local CF plant manufacturing functions.
- ❑ Deliver integration between the CF manufacturing business systems and new batch plant control system.
- ❑ Undertake all necessary infrastructure changes to IT network architecture to facilitate the Hefner project.
- ❑ Provide IS support for the re-location of production operations between sites.

The underlying principles of the project were considered to be in priority order:

1. Strict adherence to budget.
2. Objectives are achieved within the time frames specified by the overall Hefner project plan.
3. IT implementation complies with the notion of plant 'ring-fencing' (i.e. the isolated support of individual plant operations within a site).
4. Notions of best practice should be utilised wherever possible.
5. IT developments should be future-compatible with the WAVE implementation.

11.8 Analysis and Considerations

The effective delivery of IT to comply with the business objectives and principles outlined above, would prove to be a very challenging task. Neither of the manufacturing business systems contained within each of the two enterprises were clearly able to offer a viable solution, in their current formats. Whilst, the utilisation of the Premier AS400 was attractive because of its more reliable platform and support infrastructure, Vicsys was the only system for which the enterprise had in-house

technical developments skills and the IT department were confident it could deliver a reasonably effective solution.

After producing a high-level specification of the IT requirements for the project and discussing it with the account manager of the company responsible for the Premier business system, it was concluded that to extend the functionality of the AS400 based system would not be achievable within the required time-frame and at acceptable cost. Additionally, the UK President considered the selection and implementation of a completely new manufacturing system, to be totally unacceptable due to the forthcoming implementation of WAVE. As such, to remain with at least one of the established and supported platforms, meant that the Vicsys system was the only one that could really be used.

The Vicsys system had been developed internally, at the beginning of the 1980s, to closely meet the basic business needs of small independent manufacturing enterprises at low-cost. The system initially comprised functionality for costing, sales, purchasing, production control, packaging and invoicing, but was soon extended to cover additional functionality for pricing, sales analysis, management reporting, and stock valuation. The architecture of the solution was based upon a Novell Netware fileserver, a Pervasive SQL (Btrieve) database and clipper executable programs.

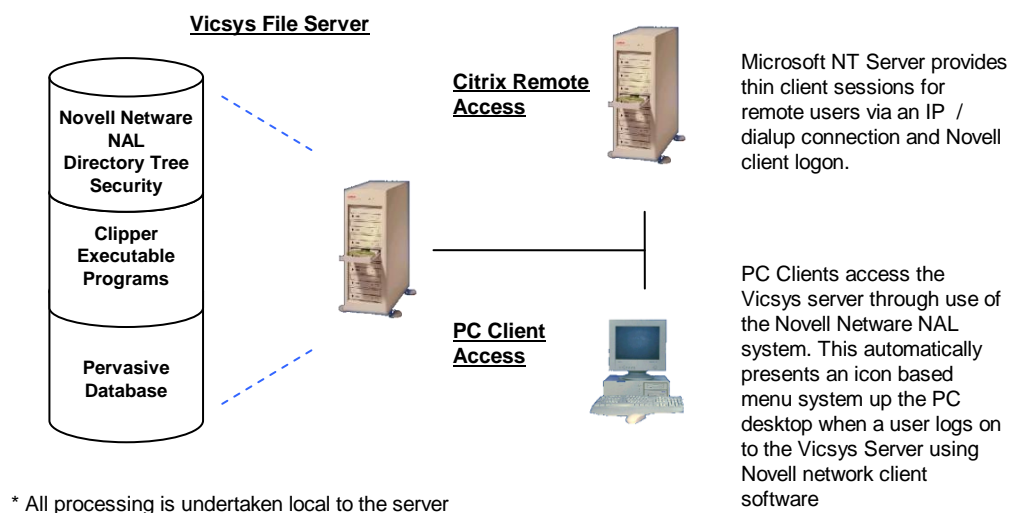


Figure 11.7: *Vicsys System Architecture.*

Access to the suit of programmes was provided by Netware's Application Launcher (NAL), Novell user/group securities and a Vicsys database data dictionary. Whilst, in

the initial phases of the Vicsys system development a dedicated support team had been assembled, this had dissolved over recent years, due to preparation for the WAVE project, IT staff moving back into individual businesses within Vesuvius and problems associated with staff retention. At present, specifically nominated IT staff distributed throughout the global Vesuvius enterprise, were nominated to provide support for the Vicsys solution. This support was co-ordinated through a Lotus Notes based problem log and was limited only to software maintenance and not additional development. An overview of a typical Vicsys architecture can be seen in Figure 11.7. A typical internal cost for the implementation of a Vicsys system would be in the region of £12,000 (i.e. two file servers, software licensing and the free to use Vicsys application).

To undertake the implementation of Hefner project upon a newly developed Vicsys system, the project steering committee recognised the following high-level specific system requirements:

❑ **It must be capable of rapid implementation.**

The complete lead-time for the whole Hefner project was set at around nine months. Whilst the project plan encapsulated additional time for small delays, the operational start date of the batch plant and the Barlborough office move were fixed.

❑ **Provide costing, sales order book control and stock management.**

Due to the time and resource constraints of the project it was acknowledged that the delivery of only key business functionality would be contained within the scope of the new Vicsys implementation.

❑ **Provide multi-enterprise / multi-manufacturing plant support.**

The overall system would have to provide support for the eight individual manufacturing plant operations located at 3 different enterprises / dispersed sites.

❑ **Be capable of remote access.**

To facilitate system access from sites other than CF (i.e. BB, KC, BW)

❑ **Provide integration with the new batch plant**

This would mean the ability to plan and schedule production effectively and to undertake the read and writing of data from / to RF tags so as to accurately manage material quantities and operational production stages.

❑ **Provide supply chain integration with suppliers.**

Due to the potentially very short production cycle-times, operational integration with key suppliers would be required to facilitate the continuous flow of raw materials to the new

batch plant. Two areas that were considered to be key were the provision of on-line inventory reporting, to allow suppliers to manage their own re-supply levels and access to item data so that they could produce pre-barcoded bulk bag labels.

❑ **Incorporate effective management reporting**

This would be required due to two specific reasons, 1) provide conformance with overall corporate standards and reporting policies and 2) provide detailed operational level reports to closely monitor the integration performance of the enlarged CF site

❑ **Support 24/7 operation.**

As the new batch plant is intended to become the primary manufacturing facility for monolithic products for the whole of the northern European region, the manufacturing operation of the plant was designed on a 24/7 basis. Computer support would therefore have to mirror this.

❑ **Data migration preparation for JD Edwards.**

All data and system coding used within the new Vicsys system should conform to JD Edwards standards to improve the migration process.

Whilst, flexibility was acknowledged as necessary system property, it was not considered to be the major determining factor in the new system design, the implementation of a basic system to support business integration without a loss of market share was. Furthermore, it was anticipated that a large degree of computer network and telephone system re-development would have to be undertaken to enable the successful completion of the project.

11.9 Implementation Methodology

To undertake successful systems implementation, the utilisation of an effective project methodology is considered to be a fundamental pre-requisite [595]. As the newly combined IT department did not yet adhere to any formal project management standards (although it shortly planned to) a suitable methodology would have to be located. Whilst Prince2 [603] was recognised as the most complete methodology available, the author decided that it would be too cumbersome to employ in total and did not realistically represent the full range of actions that would be required to realise the Hefner project objectives, i.e. technical architecture development.

In respect of this problem, the author envisaged that the part-application of the Business Strategy Driven IT Systems concept and the utilisation of his newly designed

IT Route Map would provide (1) the enterprise with a potentially valuable way forward to achieve its integration goals and (2) facilitate the author with a proof-of-concept case study implementation of his PhD thesis ideas.

After discussion with the Northern European IT manager and the Hefner management steering committee it was agreed that the Business Strategy Driven IT Systems concept would in the large be useful, but this would have to conform to general project management principles as advocated by Prince2. From analysis of the IT Route Map's composition (see Table 7.1) it was envisaged that the main project thrust would be centred around the utilisation of the Implementation Framework procedural steps, Table 11.6. These would also be supplemented with software component generation based upon particular business models, rather than the semi-generic models contained within the Business Model Template. This then would be supported by the incorporation of Systems Architecture principles into the design of the enterprise's new CF Vicsys solution. Particular models would have to be used the ETO/MTO Business Model Template and System Architecture had not yet been implemented. Project management stages and associated documentation, such as main project plan and project initiation document would be based upon standard Prince2 formats described in [603].

IT Route Map Section	Procedural Steps	Artefacts
Additional Prior Phases	A. IT technical infrastructure hardware and network redesign B. Data storage design and development C. Particular model enactment to create process-orientated software components.	Design specification Data and access definitions Software component library
Implementation Framework	12. Migration opportunity review. 13. Systems assurance and attainment of business pre-requisites. 14. Project definition and planning. 15. Implementation preparation and system install. 16. Particular model generation. 17. Software component specification / prototyping / simulation. 18. Development and confirmation. 19. System integrity and stress checking. 20. Implementation and training. 21. New system operation, support and service level definition. 22. Post implementation review and audit.	Project mandate document. Scope documentation. Project initiation and plan. Technical assessment report. Process models Component specification. Component signoff. System signoff. Readiness review. Service level agreement. Audit report.

Table 11.6: *Hefner IT Planning.*

The move of the enterprise towards more process-orientated systems, as recognised by Business Strategy Driven IT Systems, would:

- ◆ Provide greater strategic focus.
- ◆ Support the notion of manufacturing plant ring-fencing.
- ◆ Allow process performance to be easily monitored.
- ◆ Deliver processes that could be audited and improved.
- ◆ Assist in the clarification of organisational boundaries and roles.
- ◆ Impose organisational discipline, considered to be especially important in this time of great change.
- ◆ Facilitate the storage and re-use of enterprise knowledge.
- ◆ Link individuals with the work roles that they fill.
- ◆ Provide a mechanism for establishing potential resource requirements.

Throughout the implementation of the project, research data collection would be undertaken through:

1. The researcher's field notes of observations.
2. The researcher's notes pertaining to the work he was involved in (e.g. overall project management, solution design and technical implementation)
3. Related enterprise and project documentation such as project plans, presentations, memoranda, quality manuals, and technical reports.

The length of time spent investigating and working upon this project was in excess of 12 months and this is considered to be extremely important to this mode of research. Lincoln and Guba [121] state, '...we believe it to be the case that the probability that findings (and interpretations based upon them) will be found to be more credible if the inquirer is able to demonstrate a prolonged period of engagement (to learn the context, to minimise distortions and to build trust), to provide evidence of persistent observation (for the sake of identifying and assessing salient factors and crucial atypical happenings), and to triangulate, by using different sources, different methods...!.

11.10 Project Phases

The initial phases of the project largely related to the development of the technical infrastructure required to support the implementation of the Hefner project plan. The first stage of which would be the transfer of Foundry Resale Products from CF to BW and was planned for completion in less than 2 months. After much consideration, Vicsys system prototyping, preparatory design work, together with reservations from some Vicsys support staff, an acceptable technical solution was proposed. In essence this comprised three main parts (below), which closely reflect the additional prior IT Route Map phases (A to C) described in Table 11.6:

- A. Extension of IT networking facilities within and between the main Hefner sites, (i.e. CF, BW, KC and BB) and installation of a new Vicsys server within CF.
- B. Transformation of the Vicsys environment within KC to become a multi-enterprise / multi-manufacturing plant solution that was capable of supporting the majority of the Hefner project business systems requirements.
- C. The specification, design and development of new process models and software to facilitate the operation and business systems integration of the new batch plant within CF.

11.10.1 IT Technical Infrastructure Redesign (Phase A)

The IT infrastructure redesign comprised two parts. Firstly, the technical installation of a new Vicsys server within CF and secondly, the provision of network support (WAN) between the individual locations, together with internal network expansion to provide linkage between the Vicsys servers and local PC based clients (LAN).

Manufacturing business support for all of the Hefner project phases (Table 11.1) would be undertaken upon the principle of a single Vicsys system. A new high performance Novell server and Pervasive database were installed and configured at the CF site. The Vicsys environment at KC was then relocated onto the new server at CF and the KC users transferred. Access to the KC Vicsys environment now at CF, from KC, was facilitated through the use of the CF remote access server and the installation of Citrix thin client software. At this point the current CF Vicsys environment was still being operated upon its old Novell server located at CF.

Whilst, some of the inter-site networking was already in place and only required access configuration, (due to the preparation for the WAVE project), a large amount of network re-design had to be undertaken at the CF and BW sites. This

comprised the installation of additional computer nodes (computer switches and patch panels), network access points, network cabling and serial RS232 lead provision between the PCs and RF read/write heads used within the CF batch plant. An overview of the Hefner network topology can be viewed in Figure 11.8

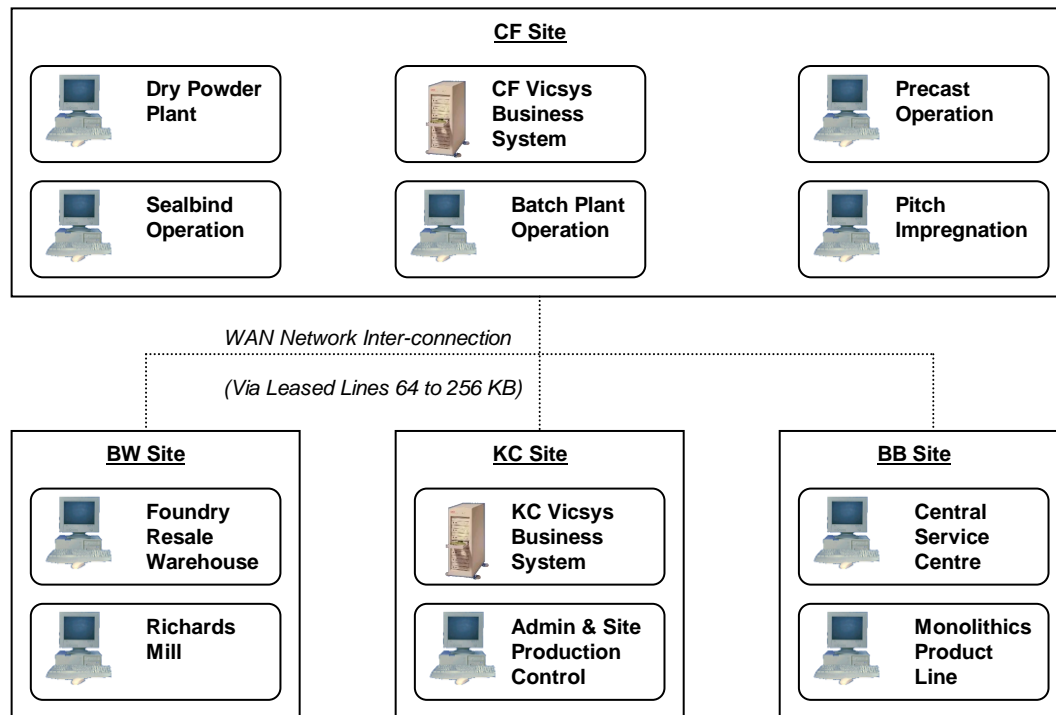


Figure 11.8: *Hefner Network Topology.*

11.10.2 Data Storage Design and Development (Phase B)

The transformation of the single site KC Vicsys solution to a multi-enterprise / multi-manufacturing plant system was achieved by the redesign and development of the Vicsys system to conform to the Systems Architecture principles, described within Chapter 9 of this thesis. This entailed separating out the various inter-linked components of the current KC Vicsys architecture, redesigning them for multi-enterprise/plant operation and then mapping them onto the System Architecture detailed by Figure 9.1.

To some dome degree a pragmatic approach had to be undertaken to this process as the design was largely constrained by the use of tools, systems and standards already employed by the existing standard Vicsys development. The primary focus of this stage was the creation of a multi-enterprise/plant Vicsys platform from

which business data and individual process-orientated software could be mapped. This was achieved by:

1. Classifying the database tables contained within the standard Vicsys system into three groups, static data, transaction data and data warehouse.
2. Extending the scope of the data tables to include functionality for the storage and identification of location codes (i.e. CF, BW, KC) and manufacturing plant (i.e. D - Dry Powder, C - Precast, etc)
3. Creating individual versions of Vicsys configuration files to represent each enterprise location. (These contain system parameters, application coding and site address detail, etc)
4. Creating individual location data dictionaries to point to the three classes of shared database files and to support the selection of specific tables where necessary, i.e. individual location configuration files.
5. Redevelopment of the Novell security and NAL menu configuration to support location specific groups of Vicsys users.

An overview of the new architecture can be viewed in Figure 11.9, its development was undertaken in a period of around 3 weeks by 4 dedicated in-house IT employees.

Achievement of data store and hardware resilience (database mirroring and dual server processing) envisaged within the Systems Architecture proposal could not be attained due to practical limitations contained within the technical architecture of Vicsys. As such the new Vicsys solution was only loosely designed upon the new Systems Architecture proposed within this thesis and did not include functional support for enterprise models and IIS business services. Consequently, to move towards a more secure environment and the goal of achieving 24/7 business support, the following actions were undertaken:

1. The old Vicsys server at KC was moved to CF and configured to act as a backup, in case of primary server failure.
2. Key Vicsys database tables would be copied from the primary data store to the secondary store upon a nightly basis. These files would also be used to support manual operation of the batch plant if Vicsys was unavailable for any short period of time.

3. New backup software was purchased to enable system backups to be undertaken upon the live system.
4. An external server maintenance and disaster recovery support contract was negotiated with 4-hour on-site response.

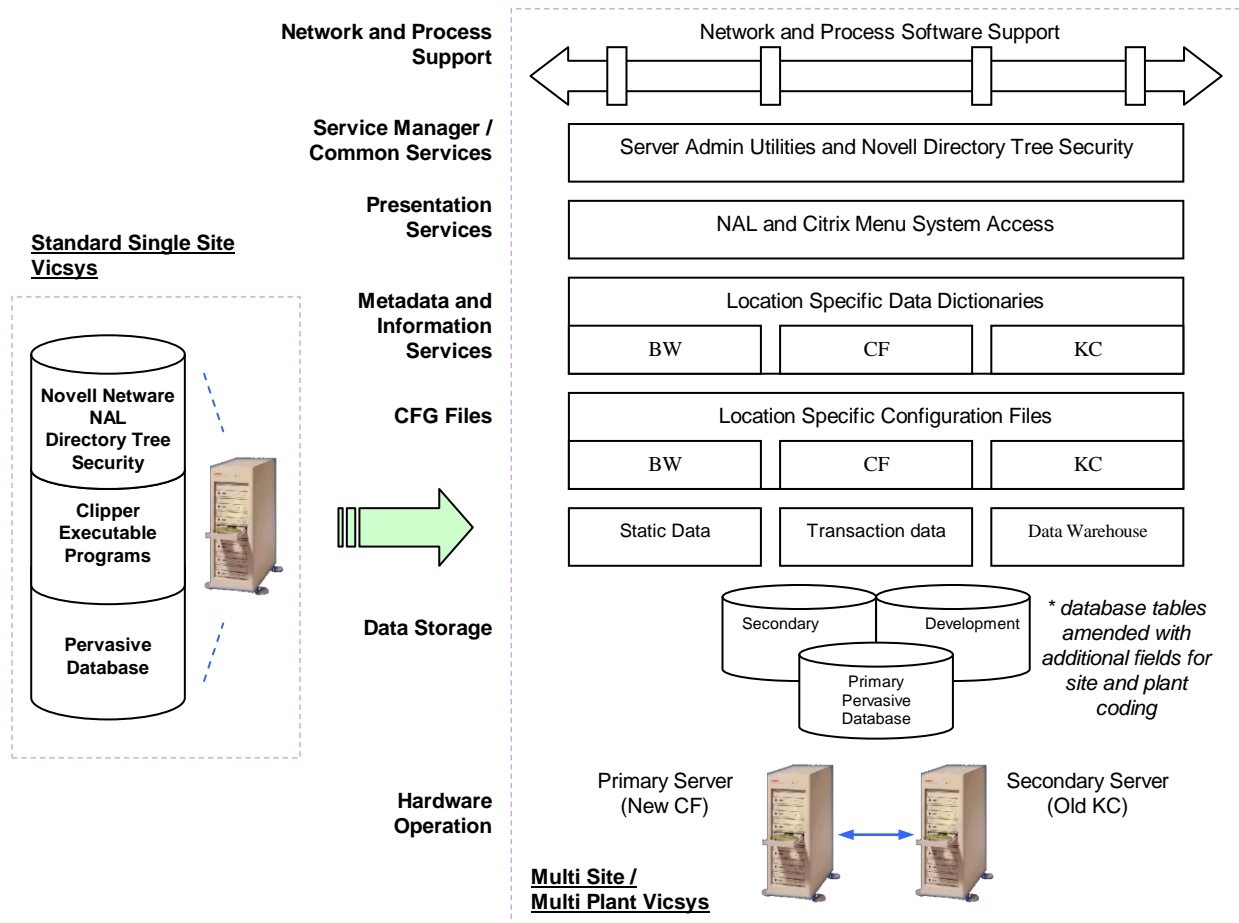


Figure 11.9: Vicsys Systems Architecture Development.

11.10.3 Software Component Development (Phase C)

Phase C represented the generation of process-orientated software components from business process models. This comprised two phases, 1) the design of Vesuvius specific (TO-BE) business process models, using the high-level core processes and the exemplar process template described within Chapter 8, and 2) the development of executable computer programmes using manual programming techniques.

Whilst, nearly all of the process models were designed from scratch using blank templates, high-level systems flow charts, Vesuvius' quality manuals and associated Vicsys documentation, the semi-generic ETO/MTO Manufacturing Execution process

(previously designed by research collaborators in Appendix D) was used as an example of how the overall Business Strategy Driven IT System concepts could be applied. As such the author and additional Vesuvius personnel utilised the semi-generic manufacturing execution model to derive a Vesuvius specific version. This was achieved by manually combining aspects of the semi-generic model with generally only the participant's personal knowledge of the enterprise's processes. The semi-generic and derived manufacturing execution process models can be viewed in Table 11.7.

Process Dimensions	Base Semi-generic Model	Vesuvius Derived Particular Model
Process Name	Manufacturing Execution	Manufacturing Execution
Identifier	BP-2	BP-12
Version	1.00	1.00
Release Date	2/4/2000	12/5/2000
Owner	Production Director	Production Manager
Description	The profitable manufacture of quality products to effectively meet customer requirements	The profitable manufacture of quality products to effectively meet customer requirements
Objectives	<ol style="list-style-type: none">5. Cost effective manufacture of products6. On-time delivery7. To achieve internal, customer and regulatory quality requirements8. To achieve Health and Safety requirements and environmental targets	<ol style="list-style-type: none">1. On-time delivery2. Continuity of product supply3. To achieve customer quality requirements
Inputs	<ul style="list-style-type: none">• High level strategic plans• Product Designs, Assembly and Engineering Specifications• Sales Orders• Item/BOMS/Routings• Resource Capacities (plant, labour, Materials)• Inventory and re-order levels• Manufacturing and Engineering Skills• Supplier Chain Interfaces• Regulatory Standards• Third Party Materials, Products and Services	<ul style="list-style-type: none">• Hefner Project Plan• Product Design and Test Specifications• Sales Orders• Item/BOMS/Routings• Resource Capacities (plant, labour, Materials)• Inventory and re-order levels• Supplier Chain Interfaces• Third Party Materials, Products and Services
Activities	EA-1 Engineering EA-2 Planning EA-3 Capacity Check and Scheduling. EA-4 Manufacture EA-5 Quality Assurance EA-6 Ship or stock	EA-1 Production Order Receipt EA-3 Scheduling. EA-4 Manufacture EA-5 Quality Assurance EA-6 Despatch
Outputs	<ul style="list-style-type: none">• Inventory (Final Products)• Production Performance Data• Inventory Information• Procurement / Supplier Status• Design and Production Feed Back	<ul style="list-style-type: none">• Inventory (Final Products)• Production Performance Data• Inventory Information• Procurement / Supplier Status

	<ul style="list-style-type: none"> • Material Yields • Labour efficiency and Overheads • Planned Maintenance Requirements 	
Systems	<ul style="list-style-type: none"> • Design Databases • ERP / MRP II / Manufacturing System • CAE, CNC Programming System • Purchase & Payroll Systems • Quality Assurance • Inventory 	<ul style="list-style-type: none"> • Technical Specification Database • Vicsys Manufacturing Business System • Process Control System • Batch Plant Controller
Transactions	<p>Routine</p> <ul style="list-style-type: none"> • Materials Flow • Shipping and Receiving • Costing Data <p>Non-Routine</p> <ul style="list-style-type: none"> • Labour Stoppages • Agency Fees and Royalties • Material and Labour Cost Variances <p>Finance</p> <ul style="list-style-type: none"> • Late Delivery Penalties • Recall and Warranty Provisions • Inventory Write Off 	<p>Routine</p> <ul style="list-style-type: none"> • Materials Flow • Shipping and Receiving • Costing Data <p>Non-Routine</p> <ul style="list-style-type: none"> • Labour Stoppages • Agency Fees and Royalties • Material and Labour Cost Variances <p>Finance</p> <ul style="list-style-type: none"> • Late Delivery Penalties • Recall and Warranty Provisions • Inventory Write Off
Risks	<p>A. Plant unable to achieve design tolerance (1,3)</p> <p>B. Inaccurate / Inadequate sales forecasting (1)</p> <p>C. BOM Inaccuracy (1)</p> <p>D. Inaccurate inventory records (1)</p> <p>E. Inefficient plant utilisation (1,3)</p> <p>F. Ineffective capacity planning (1)</p> <p>G. Lack of production / process flexibility (1,3)</p> <p>H. Environmental controls within manufacturing (4)</p> <p>I. Safety process and training (4)</p> <p>J. Unskilled workforce (3,4)</p> <p>K. Inadequate inbound / outbound logistics (2)</p> <p>L. Poor internal communications / employee morale (1,3)</p> <p>M. Plant breakdowns (1,3)</p>	<p>A. Vicsys System Breakdown (1)</p> <p>B. BOM Inaccuracy (1,2)</p> <p>C. Inaccurate inventory records (1)</p> <p>D. Inefficient plant utilisation (1)</p> <p>E. Ineffective capacity planning (1)</p> <p>F. Safety process and training (1,2)</p> <p>G. Unskilled workforce (1,2,3)</p> <p>H. Workforce shortages (1,2,3)</p> <p>I. Inadequate inbound / outbound logistics (1,2)</p> <p>J. Poor internal communications / employee morale (1,2,3)</p> <p>K. Plant breakdowns (1,2)</p>
Controls	<p>⇒ CE, design for manufacture (A)</p> <p>⇒ Past performance forecast (B)</p> <p>⇒ Regular checking / error logging (C)</p> <p>⇒ Perpetual Stock checks (D)</p> <p>⇒ Production planning & scheduling (E)</p> <p>⇒ Production performance monitoring (F)</p> <p>⇒ Design for process improvement (G)</p> <p>⇒ Control systems and standards (H)</p> <p>⇒ Monitoring and training programmes (I)</p> <p>⇒ Formal assessment programmes (J)</p> <p>⇒ Logistics performance monitoring (K)</p> <p>⇒ Employee assessment via group reviews and questionnaires (L)</p>	<p>⇒ Disaster Recovery Procedures (A)</p> <p>⇒ Regular checking / error logging (B)</p> <p>⇒ Perpetual Stock checks (C)</p> <p>⇒ Production planning & scheduling (D)</p> <p>⇒ Production performance monitoring (E)</p> <p>⇒ Monitoring and training programmes (F)</p> <p>⇒ Recruitment and Incentives (G)</p> <p>⇒ Logistics performance monitoring (I)</p> <p>⇒ Employee assessment via group reviews and questionnaires (J)</p> <p>⇒ Preventative / planned maintenance (K)</p>

	⇒ Preventative / planned maintenance (M)	
CSFs	<ul style="list-style-type: none"> • Delivery on time (2) • Design integrity (1) • Manufacturing cost control (1) • Manufacturing flexibility (1) • Plant utilisation (1) • Material utilisation (1) • Quality control (3) • Cost of quality (1) • Safety (4) • Inventory accuracy (1) • Optimum inventory levels (1) 	<ul style="list-style-type: none"> • Delivery on time (1) • Design integrity (1) • Plant utilisation (1) • Inventory accuracy (1) • Optimum inventory levels (1) • Integration planning (2) • Quality control (3)
KPIs	⇒ Order backlog ⇒ Number of design changes ⇒ Cost variance analysis (CVA) ⇒ Manufacturing lead-time ⇒ % plant utilisation ⇒ Materials Usage versus planned / CVA ⇒ Rework and scrap cost analysis ⇒ Inspection, verification, testing costs ⇒ Nos. of accident free days ⇒ % stock check accuracy ⇒ Inventory turns	⇒ Manufacturing lead-time ⇒ % plant utilisation ⇒ Rework and scrap cost analysis ⇒ Inspection, verification, testing costs ⇒ Nos. of accident free days ⇒ % stock check accuracy ⇒ Inventory turns
Competence	Level 1 Production Planner	Operations Planner
Standards	ISO9000, 4.7, 4.8, 4.9, 4.10, 4.12, 4.15	Vesuvius Quality Manual
Problems	7 Excessive downtimes 7 Excessive set up times 7 High inventory levels 7 Higher level of planned component replacement 7 Poor employee relations 7 Premium labour costs (overtime) 7 Cost of emergency shipment 7 Late to deliver	7 Plant readiness 7 Excessive downtimes 7 High inventory levels 7 Access to skilled employees 7 Premium labour costs (overtime) 7 Late to deliver 7 Loss of customers
Kaizen	✓ BPR ✓ Benchmarking ✓ ISO 9000 and IIP ✓ Inventory Management ✓ Procurement Performance ✓ Manufacturing Systems ✓ Project Design ✓ Design Management ✓ Overhead Cost Reduction ✓ CAD/CAM	✓ Business Strategy Driven IT Systems ✓ Business Prerequisites ✓ Business Excellence ✓ Inventory Management ✓ Finite Scheduling / APS ✓ Logistics Planning ✓ Procurement Performance ✓ Overhead Cost Reduction

Table 11.7: *Manufacturing Execution Process Models*

The derivation of the Vesuvius manufacturing execution model from the semi-generic model supplied could be seen to be in the order of three to five times faster than building the model directly from scratch. Both though would have to undergo subsequent validation to guarantee a firm foundation upon which to initiate the process of software component development.

Due to the time constraints placed within the overall Hefner project, it would have been unachievable to completely re-implement the whole of the Vicsys manufacturing business system to represent a completely process-focussed solution. In respect of this, it was considered more practical to separate out the function-based computer programs of the standard Vicsys system into individual applications and then modify these generic applications to (1) incorporate the database changes required for multi-enterprise/plant system operation and (2) enable combinations of Vicsys applications and CSF/KPI support reports to be effectively deployed to support the (TO-BE) business process models designed earlier. It was envisaged that, whilst not completely representing the notion of process-orientated software components, the newly developed modular applications could be stored within a library and distributed in much the same way as the components. In total 11 application modules were developed that would collectively provide functional support for most of the enterprise's business process models (See Table 11.8). One major exception to this provision was a mechanism for facilitating the integration of operations with the batch plant (e.g. RF tags and associated inventory transactions).

Code	Application Name	Description
DD	Data Dictionary	System Manager utility for maintaining Pervasive Database data dictionaries
CFG	Configuration	System Manager utility for maintaining Vicsys configuration files
V_MENU	Table Maintenance	Used to maintain customer and sales details
COS	Costing	Used for production item/BOM/routing and cost control
OSI	Orders, Sales and Invoices	Used for sales order management processes
PUR	Purchasing	Creation and maintenance of suppliers and purchase orders
MRP	Material Reqt's Planning	Production scheduling
PR	Production Reporting	Used to undertake discrete production operations, inventory and transactions
PLT	Pallet Packaging	Used to label and package discrete finished goods
VQC	Vicsys Quality Control	Used to undertake batch production, inventory, transactions, quality and packaging
VAL	Valuation	Used to produce stock valuations upon standard and actual costs
PCS	Process Control System	Used to control batch plant and RF Tag interfaces (to be developed)

Table 11.8: *Vicsys Application Modules*

To develop this functionality two bespoke developments were envisaged, (1) a new process control system application to facilitate the launching of production batches through the plant, together with RF tag maintenance and (2) modifications to the VQC application to allow the consumption of raw materials and production transactions once production batches had been produced. A production batch can be classed as a specific quantity of mix and could cross several batch plant tote bins. Figures 11.10 and 11.11 provide a sample view of the PCS and VQC applications, whilst Figure 11.12 show the overall batch plant process flow upon which the construction of the PCS software was developed.

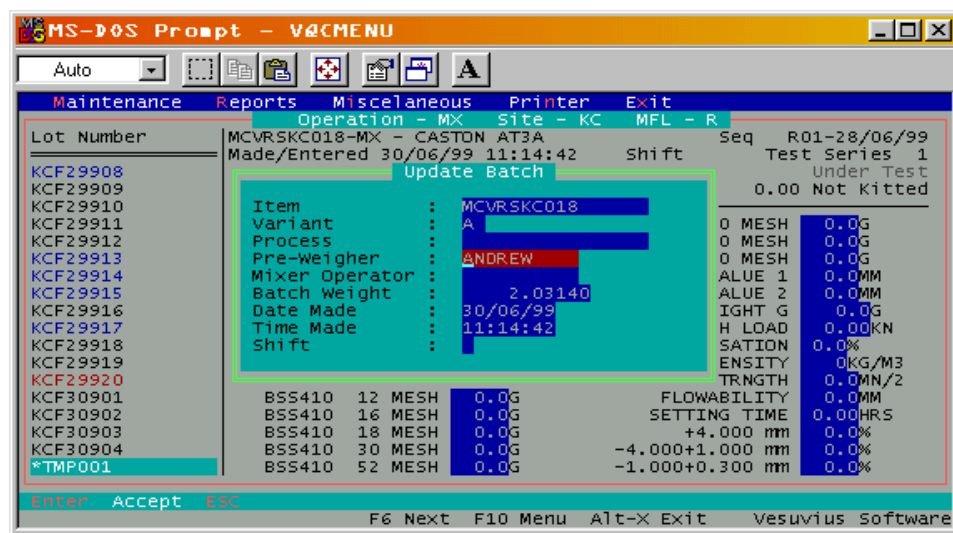


Figure 11.10: Sample Screen of the VQC Application

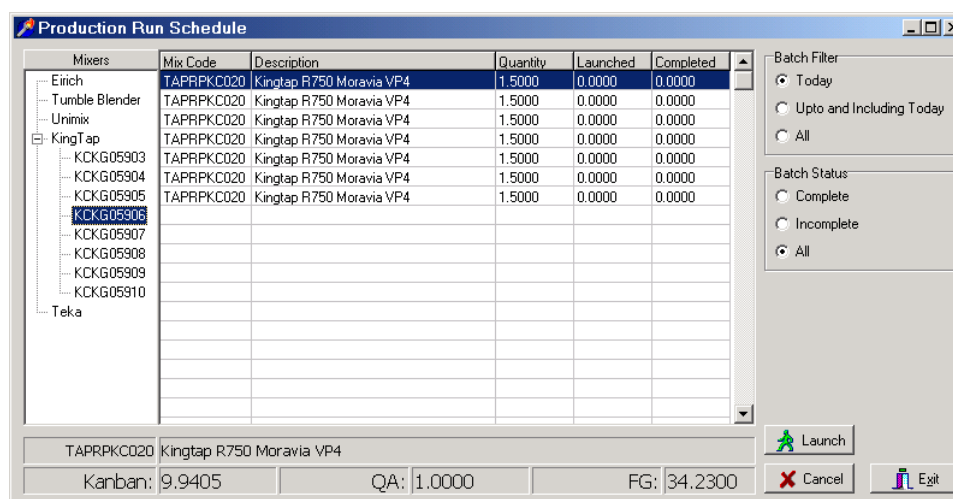


Figure 11.11: Launch Screen of the PCS Application

Error! No topic specified.

Figure 11.12: *Batch Plant Operational Process Flow.*

Whilst the existing Vicsys applications were modified in their own native programming language, (i.e. clipper) the development of the PCS application was undertaken using Borland Delphi. This was chosen as it had a number of benefits over other contemporary programming languages such as C++. These were considered to be, the ability to mix object-oriented programming with components such as ActiveX, its inherent support for Btrieve databases through the Borland Database Engine (BDE), and its ability to generate native executables. Although not fully CORBA compliant Delphi does have the ability to create COM ORBs since it supports OLE automation. [604]. After a full design specification was created, the PCS application was programmed by one of the IT team working on the Hefner project. After much testing it was released for inclusion with the other group of Business Strategy Driven IT System designed Vicsys applications. These applications together would comprise a list of configurable 'components' that would then be stored in a library and deployed individually or collectively to meet any of the Hefner business process requirements.

Furthermore to support wider enterprise business and Business Strategy Driven IT Systems requirements a number of other application modifications/additions were made. These comprised:

1. Modifications to Vicsys inventory transaction program routines to include the on-line update of MRP requirements as well as actual inventory figures. This was termed 'Fly-MRP' and would be undertaken upon changes in raw-material, work-in-progress and finished goods. This would present more accurate and timely stock availability from which sales personnel could then more effectively allocate stock and production schedulers plan accordingly.
2. Modifications to the sales invoice posting program so that every time an invoice was finalised a copy of the necessary database information would be written to the data warehouse tables. This was considered useful, as it would remove the need for batch data extracts and facilitate improved live system performance through the removal of some interactive report queries.

3. The creation of Crystal and Cognos business intelligence reports, based upon process CSF/KPIs, to deliver improved process performance monitoring.
4. The presentation of the newly developed process models, performance figures and key business reports upon the enterprise's Lotus Notes based intranet.

Overall, it was considered that the provision of these three prior IT Route Map (see Figure 11.6) steps would provide the combined enterprise with a valuable foundation upon which individual elements of the Hefner project could be securely delivered.

11.10.4 Systems Implementation

The overall approach to the implementation of the Hefner project was to recursively apply the IT Route Map Implementation Framework to each of the project's constituent phases (Table 11.1). This would be based upon the separation, transfer and re-implementation of individual plant operations, contained within the previous KC and CF Vicsys systems, to the newly created Hefner Vicsys environment.

The underlying rationale for this approach was that each time an individual operation was re-implemented on the new server, a shift to plant ring-fencing and achieving excellence of operations could be made. This would be undertaken by the reassignment of people's job roles combined with moves towards attaining the business excellence success criteria defined within procedural step 2 of the Implementation Framework. For each plant, a new production co-ordinator would be put in place, to implement, manage and develop individual plant operations. They would be responsible for all Vicsys business process aspects of the manufacturing plant, together with inventory control and delivery reliability. Sales, purchasing and accounts support would be delivered to the local plant operation through the new Service Centre at BB. Through the re-implementation process, data (item, BOMS, routings, customers, suppliers and generic system coding) validation and cleanup could then be undertaken in preparation for the forthcoming WAVE implementation.

The first step of the Implementation Framework to be deployed consisted of the 'migration opportunity review'. This consisted of bringing relevant people together, to communicate the project plan, brainstorm ideas that would successfully enable the required changes and to produce a project mandate document. The project mandate document generally contained the responses from the executive responsible for the

project phase, phase objectives, phase participants, expectations and an outline business case.

The second procedural step, 'systems assurance and the attainment of business pre-requisites' typically comprised the definition of the Hefner project's scope, the definition of roles and performance measures. Whilst the attainment of data accuracy, on-time delivery and high levels of supplier performance were acknowledged as worthy goals, they were not generally implemented prior to equipment and system re-locations, due to the time and personnel constraints involved.

For each project phase a project initiation document and a project plan were created to form a basis for its management and the assessment of overall success and to measure progress against, respectively. The project plans were based upon a traffic light system where each different colour represented the status of a project activity, Figure 11.13

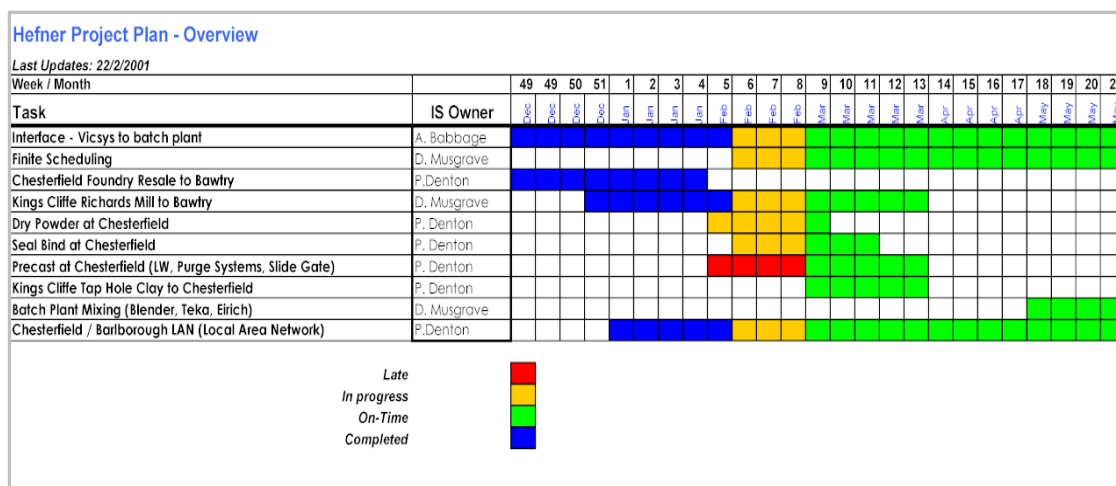


Figure 11.13: *Hefner IT Planning.*

The next six stages of the Implementation Framework (procedural steps 4 to 8) comprised the specification, installation, configuration and testing of the new process-orientated Vicsys applications for the requisite plant's operation. The specification was primarily based upon the product group that the manufacturing plant produced, i.e. discrete or batch (see Table 11.3). The VQC application would be utilised to support batch production operations, whereas the PR and PLT applications would be deployed to support discrete manufacturing. Secondary considerations related to where other business processes would be undertaken and by whom.

In relation to the transfer of the Richards Mill from KC to BW, it was anticipated that the plant's operation would be separate from the other existing manufacturing operations within the BW location. As such, during the interim period to KC closing and the Service Centre becoming live, the sales department at CF managed the Richards Mill sales order book, whilst purchasing support was provided by employees at KC. Vicsys support at BW was then only limited to production control, quality and goods despatch. The selection of Vicsys application required at each location can be seen in Table 11.9.

The installation and configuration of these applications consisted of loading the executable program files onto the live Vicsys environment, amending the relevant application configuration parameters to conform to any specific plant requirements, the set-up of users, and the release of complementary performance reports and associated process documentation. After testing the application's integrity and functional operation the individual environment could be released to the new plant production co-ordinator. Application training was undertaken by the production co-ordinators based on the process documentation provided on the enterprise's Intranet as well as visits to other manufacturing locations / plants.

Vicsys Location	CF					BW		KC
Manufacturing Plant	Dry Powder	Sealbind	Precast	Monolithic (Batch Plant)	Pitch Impreg-nation	Foundry Resale	Richards Mill	Monolithic (Mixers)
Vicsys Applications	DD	DD	DD	DD	DD	DD	DD	DD
	CFG	CFG	CFG	CFG	CFG	CFG	CFG	CFG
	COS	COS	COS	COS	COS	COS	COS	COS
	MRP	MRP	MRP	MRP	OSI	V_MENU	MRP	MRP
	OSI	OSI	OSI	OSI		OSI	OSI	OSI
	PUR	PUR	PUR	PUR		PUR	PUR	PUR
	VQC	PR	PR	VQC			VQC	VQC
		PLT	PLT	PCS				

* The BB Service Centre would have Vicsys application provision for each of the manufacturing plants comprising: V_MENU, OSI, PUR, COS and VAL.

Table 11.9: *Vicsys Application Deployment*

Once the first phase of the system was live, an IT service level agreement (SLA) was negotiated between the UK IT operations manager and the primary business sponsors of the project. The SLA consisted of definitions of supported systems and services, a categorisation of agreed response times and a set of problem escalation procedures. The benefits of using a SLA were recognised by the enterprise as:

- ◆ A list of services and systems supported are agreed between the business and the IT Department.
- ◆ The acceptable response times are agreed with the business.
- ◆ The response times are logged electronically and this provides measurement. The times can be analysed and investigated.
- ◆ Trends on efficiency will allow smarter working practices; this will be especially useful when response times are below standard.
- ◆ Workload from specific parts of the company or specific systems will determine how IT resources are tasked. This may point to specific areas of improvement via simple fixes or education.
- ◆ The process is a vehicle for communication and interplay between the business and the IT Department.
- ◆ The business can pressure the IT Department to reach agreed service levels if they fail to perform adequately.
- ◆ The process pushes for continual improvement.
- ◆ All parties have a common set of measurements to refer to; this removes the subjective approach taken so far.

The final stage of the Implementation Framework consisted of the post implementation review and audit. This was undertaken after each completed phase of the Hefner project and its primary focus was centred on determining whether or not the expected benefits had been obtained. It included, measuring actual system performance against the four categories of systems acceptability, (Technical, Ergonomic, Organisational and Ethical) as defined by Preece [606]. The outcome of each review comprised of an individual audit report.

11.11 Project Results

In the period October 1999 to June 2000 the following Hefner IT project phases had been completed:

- ✓ Technical installation of the new Hefner Vicsys server within CF and network redesign.
- ✓ Vicsys infrastructure and Pervasive database development to support the IT Route Map Systems Architecture principles.
- ✓ Redesign of original, standard Vicsys system programs to conform to process-orientated component concepts.
- ✓ Development of a new process control application to manage the operation and integration of the newly installed manufacturing batch plant.
- ✓ Transfer of the Foundry Resale warehousing from CF to BW and then from BW to the Vesuvius Workshop site. The additional Workshop transfer was outside the original remit of the project scope and had to be subsequently undertaken due to unforeseen problems, i.e. product degradation due to adverse environmental conditions within the new warehouse and a requirement for facility expansion.
- ✓ Transfer of the Richards Mill and associated administrative functions from KC to BW.
- ✓ Revitalisation and transfer of CF Dry Powder plant operations from the old CF Vicsys environment to the new Hefner Vicsys environment.
- ✓ Revitalisation and transfer of CF Sealbind operations from the old CF Vicsys environment to the new Hefner Vicsys environment.
- ✓ Transfer of the Precast operation from the old CF Vicsys environment to the new Hefner Vicsys environment. This was only undertaken as it was previously implemented upon the CF Vicsys, and not fully revitalised due to the production co-ordinator responsible for the plant leaving the enterprise to undertake maternity leave.
- ✓ Installation and configuration of the new Hefner Vicsys system to facilitate the administration and control of the manufacturing batch plant and its associated production equipment, i.e. bin emptying / filling, tumble blender, mixers, etc.
- ✓ Relocation of UK Head Office and Monolithics Product Line employees and systems to the new BB offices.

Overall the majority of the IT objectives encompassed within the Hefner project were completed on-time, within budget and in no way impacted upon the progress of the Vesuvius-Premier integration effort (the key business issue). Whilst it is largely difficult to accurately measure the overall success of the project in pure financial

terms, because it was so far reaching and dynamic, the following scorecard can be used to summarise some of the successes and failures of the project:

- ✓ Full ERP systems development and implementation completed within a time frame of around nine months.
- ✓ Systems implementation completed with the utilisation of in-house resource and skill. This maintained a very low cost, i.e. 120-user system, supporting aspects of 5 different sites (inclusive of Worktop) at an initial financial outlay of less than £50,000. (Approximately £20,000 hardware and software / £30,000 network redesign and expansion).
- ✓ Process focus supported the strategic notion of the 'ring-fencing' of manufacturing plant operations and with well-formed business intelligence reports, facilitated the close monitoring of plant performance linked to business strategy.
- ✓ Delivered near 24/7 operation with the removal of the requirement for exclusive batch processes such as backups and sales data extraction.
- ✓ Delivery of improved availability-to-promise through the development of 'Fly-MRP' concepts.
- ✓ Reduced requirement for dedicated Vicsys IT support personnel from 4 to 1.
- ✓ Continuity and development of customer supply.
- ✓ Increased data accuracy throughout the system and an improved ability to achieve the forthcoming migration from Vicsys to JD Edwards.
- 7 Considerable under-estimation of the actual resource required to implement the whole project. A problem further compounded by recruitment restrictions and the timeliness with which some people could relocate between Hefner sites.
- 7 Poor communication of the Hefner project vision, which led to feelings of uncertainty and poor morale.
- 7 Inability to immediately tackle all business issues and problems uncovered through the re-vitalisation processes, e.g. poor Vicsys system print performance using Citrix remote access clients.
- 7 Slow development of new standard costing models for each of the new plant configurations.
- 7 Poor contact control of the primary batch plant supplier. Acceptance of equipment that had not been fully tested and signed off, in respect of achieving its required levels of functionality and performance.
- 7 Movement of project milestones due to unforeseen circumstances and lack of detailed project planning.

- 7 Gradual reduction in senior executive attendance at Hefner management meetings, as the project progressed and its profile was replaced by more pressing business issues, e.g. large downturn in market conditions.

The deployment of Business Strategy Driven IT Systems concepts to underpin the whole of the Hefner integration project was generally agreed by the project participants to have provided a valuable contribution to the business goals of the enterprise. It was encouraging that the Hefner project committee felt that the implementation of this process-orientated approach could be utilised for many more purposes other than just enterprise business integration, e.g. as an approach to BPR whereby enterprises are endeavouring to identify core business areas, which they must focus and develop total competitive advantage in.

A comparison of lead-time and costs between the Business Strategy Driven IT Systems enterprise engineering methodology for manufacturing business system implementation against what current literature and the author's personal experience considers to be reasonable estimates of state-of-the-art ERP deployment techniques can be seen in Table 11.10.

Comparison Item	State-of-the-Art	Business Strategy Driven IT Systems
Time to build particular model enterprise model	6 months	2 Months
Reduction in model engineering time		3:1
Time to re-use model in a similar plant	4 months	15 days
Reduction in model engineering time		8:1
Time to define measurement controls reports	2 months	15 days
Reduction in CSF/KPI analysis		4:1
Time to specify software requirements	6 months	2 months
Reduction in software specification time		3:1
Time to installation software and configure	1 month	1 week
Reduction in software set-up time		4:1
Time to train users	2 months	1 months
Reduction in user training time		2:1
Annual support requirements (manpower)	4	1
Reduction in support		4:1
Overall time to implement	18-24 months	9 months
Overall cost (120) user system	> £250,000	£50,000

Table 11.10: *Methodology Comparisons*

Through the decomposition of an enterprise into processes, (which represent an 'end-to-end' business view), questions relating to performance are often asked, i.e. when a production co-ordinator receives an order enquiry 'How long will it take to flow through the manufacturing plant?'. Work is then perceived to be a flow from the customer, through the enterprise, serving a strategic purpose.

Previous functional based departments such as sales and purchasing, will still undertake activities within the new flow, but the difference is a change in focus from internal efficiency (i.e. the number of orders processed within a day) to business objective achievement (i.e. are the activities meeting customer requirements?). The embedding of CSF and KPIs, that are based on and are directly linked to process objectives and business strategy, into process operation has provided the enterprise with a foundation for driving customer service and business improvement.

11.12 Summary

This case study work has deliberately covered much ground and its main thrust of semi-automatically generating process-orientated software components are largely conceptual at this stage, even though their origin is based upon enterprise engineering principles developed through acknowledged research study.

The pilot implementation has rapidly delivered to the enterprise a system, which meets its original business requirements, as well providing a foundation for any further system expansion and an opportunity to successfully migrate to a new ERP platform. Overall, without the employment of such an enterprise engineering methodology (i.e. Business Strategy Driven IT Systems concepts combined with an IT Route map implementation approach) it was agreed by the project participants that the Hefner integration project may not have succeeded.

CHAPTER 12

CONCLUDING DISCUSSIONS

12.1 Introduction

This discussion brings together a number of major issues of the research reported in this thesis in order to formulate the conclusions.

12.2 Research Overview

The research conducted with this thesis can be viewed as being novel as it presents a new approach to the creation and deployment of manufacturing business systems within SMEs. Through the review of academic literature it is considered that no similar work is currently available that focuses upon such a holistic approach and is based upon a firm foundation of descriptive and experimental research.

The Business Strategy Driven IT Systems concept and IT Route Map developed by the author are original and stress the importance of applying process focus and enterprise engineering concepts to promote agility and to act as a foundation for business systems development within ETO/MTO SMEs. This combined approach encourages strategy driven solutions to be (a) specified based upon the use of emerging enterprise engineering theories and (b) implemented and changed using component-based systems design and composition techniques.

This work has been partially applied within an industrial case study and can be seen to offer SMEs flexible, low cost and quick-to-implement systems that are aligned to business strategy and objectives.

12.3 Design and Deployment Issues

The research conducted within this thesis has raised several new concerns related to the ability of ETO/MTO SMEs to successfully implement current manufacturing business systems. Whilst some of these can be recognised as limitations closely associated to SMEs barriers to growth such as finance and skill, others have been exposed as fundamental issues in the design of deployments of such systems. These include:

- 1) MRP based systems do not readily lend themselves to ease of computerisation of ETO/MTO production processes nor do they effectively support available-to-promise and 'what-if' simulation concepts.
- 2) ERP systems cannot effectively support global supply chain or M&A processes as they are inwardly focussed and generally do not provide effective systems integration support.
- 3) The use of complementary IT systems, such as electronic commerce, EDI, BI or CRM or now routinely 'bolted-on' to ERP system to infer business process support within a modularly designed system, but this generally leads to extended integration and support issues.
- 4) As ERP systems are based upon the notion of an ever-extending central database and typically provide limited facilities for data archival, data integrity and proliferation can become a universal problem.
- 5) ERP systems are typically founded upon a batch scheduling philosophy and as such cannot effectively support 24/7 availability or near zero-latency.
- 6) The minimum personnel requirement to competently operate and support a basic ERP system can be prohibitive for many SMEs.
- 7) The time taken to implement an ERP system is found to regularly involve a 2-year period, whereas the research results show that a 12-month period to be a more appropriate time-scale.

Overall, this research work has shown that current ERP systems are failing to meet the business requirements of contemporary ETO/MTO SMEs in a number of key areas. Unless fundamental changes are made to the design and way in which these systems are implemented, enterprises may be further beset by erosion of competitive advantage and inability to successfully implement their defined global business strategies.

12.4 Business Strategy Driven IT Systems

Enterprise engineering and component-based system concepts have recently emerged to the fore in the field of manufacturing business systems research. These concepts are concerned with intra and inter enterprise operations and with improving their efficiency

and effectiveness. The main rationale behind this new academic work can be seen as the development of systematic ways in which enterprise structures, systems and processes can be developed. Many different enterprise reference architectures and tools have been created but no one, is recognised as being able to offer comprehensive life-cycle support, depth of information completeness and degree of usability to be used on an individual basis.

Whilst recent work has focussed on standardisation and modelling, it has been suggested that when using an enterprise engineering approach it can be difficult to convert from requirements definition or high level design to real implemented systems. Moreover the number of actual implementations in which enterprise engineering concepts have been deployed, tested and validated within SMEs is very limited.

Within this context the notion of Business Strategy Driven IT Systems was conceived to promote the development of agile and innovative business activity within SMEs by developing effective integrated, end-to-end IT solutions targeted at realising the business strategy of the enterprise. The concept was defined and firmly based on the widespread academic belief that in any enterprise there should be a high degree of alignment between IT and business strategies.

Within this thesis, extensive surveys, case studies and collaborative modelling work has highlighted the need for improvements in manufacturing systems design and implementation techniques. The contribution of this objective of the research work has been to offer an alternative perspective upon which manufacturing business systems are founded. The main feature of this concept is that all IT within an enterprise should be simple, process focussed and designed to support the attainment of business process performance targets and business objectives.

Whilst, the notion has only been partially proven within a single case study implementation, it is recognised by the collaborating industrial research partners as a concept worthy of further examination and trial.

12.5 IT Route Map Design and Implementation

The IT Route Map approach to enterprise engineering based upon the Business Strategy Driven IT Systems concept and developed within this thesis can be seen to provide an agile and practical process-based alternative to typical ERP systems

deployment. The preliminary stages of Map development encompassed case study work, business process modelling, new systems requirements capture and design validation. Common ETO/MTO SME characteristics were identified and then developed into a 'Business Model Template' or reference model, comprising a business control framework, semi-generic process models and associated process-based software components. The developed IT Route Map supports business agility and innovation as it allows the rapid development and configuration of business processes, both new and existing, to meet fast-changing business requirements. Recommendation was made that these assets should be managed and maintained within a public domain repository to improve information sharing, best practice and to reduce SME costs.

An overview of a Systems Architecture was presented to provide a foundation upon which the implementation of new reusable, component-based systems could be supported. Whilst largely conceptual at this moment in time it was found that its requirements would provide a useful basis from which anyone considering the development of next-generation manufacturing systems could build.

Additionally, an Implementation Framework was specified and tailored within the IT Route Map to provide SMEs with an appropriate methodology to ensure the effective delivery and timely achievement of implementation goals. Overall the collaborating research partners confirmed that they had benefited in the following ways:

- ✓ They have received the benefit of an independent audit of their business processes.
- ✓ Process maps, in the format of SSADM-based 'Life of an Order' document, have been produced.
- ✓ Reviews of partner strategies, against the developed ETO/MTO SME industrial characterisation have highlighted opportunities for business and systems improvement.
- ✓ The industrial partners now have improved understandings of contemporary manufacturing business systems issues and limitations, thereby enabling them to better specify their own IT and communicate system requirements to potential software vendors.
- ✓ The use of a holistic enterprise engineering approach has offered a new and fresh perspective for supporting enterprises throughout their full life cycle.

An additional suggestion of the research is that the developed Business Model Template concept could be equally, successfully applied to any industrial sector. Using the IT Route Map approach, an enterprise will be able to compare, design, benchmark, specify, implement and support manufacturing business systems in a more responsive and cost effective way. Whilst the work provides a reasonable representation of how business strategy derived enterprise models may be enacted into process-orientated software components and supported, formal methods and widely recognised standards to support this process are yet to be devised.

12.6 Research Concept and Route Map Evaluation

From the pilot implementation of the research concepts the subsequent results seem very encouraging, both in enterprise model construction and software development. The derivation of business processes models from business strategy demonstrates a distinct relationship to achieving competitive performance through statement of and focus upon clear objectives, CSFs and KPIs.

The conventional approach adopted by software vendors to the implementation and design of ERP systems is typically sequential and based upon a centralised three-tier software architecture comprising, computer operating system, relational database management system and modular applications compiled using fourth-generation programming languages. These modular applications are generally functional in nature, are inflexibly constructed and centred around a core material requirements planning engine. Performance in this respect is targeted towards functional efficiency rather than the achievement of business objectives.

Scope of functionality may comprise focussed modules for sales, manufacturing management, purchasing, distribution, finance, warehousing and human resources. These modules can then be configured to match any enterprise's specific requirements. In general most ERP systems have been designed for large enterprises and usually require a substantial resource commitment to install effectively. Recent developments in the ERP field include moves to Internet enablement of systems, extensions of functionality to cover extended supply chain activities and improved interfaces to support connectivity with complementary IT systems.

However, this design structure can produce a plethora of individual and insular solutions that are inherently closed in nature and provide little or no real integration abilities. Furthermore, there can be a number of real business and technical issues associated with the deployment of such systems and they can be very expensive to purchase, implement and support.

The re-design of manufacturing business systems based firmly upon process-orientated Business Strategy Driven IT Systems concepts, recommended and supported by the author, may be seen to represent a major-step change in industrial practice. From the foundation of an effective underlying system architecture, software components will be able to be deployed, to meet an enterprise's strategic requirements in a holistic, flexible and change capable way.

The author has demonstrated the general applicability of such concepts through successful pilot implementation within an ETO/MTO enterprise undergoing widespread business change. The requirement may now be seen as the creation of all-encompassing enterprise engineering tools.

CHAPTER 13

CONCLUSIONS AND FURTHER RESEARCH AVENUES

13.1 Introduction

This chapter identifies the conclusions drawn from the research and case study implementation, together with possible further research avenues to extend the application of the Business Strategy Driven IT Systems concept.

13.2 Conclusions

The conclusions formulated from this work are as follows:

- i) SMEs have their own unique identities, resource constraints and complexities which require special consideration. Whilst manufacturing business systems are routinely used within SMEs, survey and industrial case study work has revealed a shortfall in the perceived benefits to be gained from their deployment. The reasons for failure include degree of business strategy alignment, lack of executive management support, extended implementation times, inadequate project planning, mismatches between desired and available system functionality and the resource requirements needed to complete the implementation.
- ii) The direct alignment of IT to business strategy using a process-focus is an effective way to organise an enterprise. Key business processes for the ETO/MTO industrial domain have been identified as Design and Development, Business Growth and Marketing, Sales, Sales Order Fulfilment and Service. From the implementation of Business Strategy Driven IT System concepts enterprises may expect to achieve a higher degree of agility and innovation, combined with a reduction in non-value added activities.

- iii) The deployment of the developed IT Route Map approach can offer enterprises significant benefits over contemporary manufacturing business systems design and implementation techniques. The utilisation of an ETO/MTO Business Model Template can provide enterprises with a foundation to encapsulate industrial knowledge and best practice and to reduce lead-times of process-orientated software development. The Systems Architecture development can provide enterprises with a valuable foundation upon which next-generation manufacturing business systems can be built and the structured Implementation Framework can promote rapid and less-complex systems deployment.
- iv) The pilot case study reported in Chapter 11 has proved the applicability of Business Strategy Driven IT Systems concepts and the IT Route Map approach through deployment within an SME environment. Overall the utilisation of pre-engineered, semi-generic business models and re-configurable component-based systems can significantly reduce system development times, improve flexibility and promote re-use.

13.3 Further Research Avenues

Further work is required to extend the scope and functionality of the Business Strategy Driven IT Systems concept in the following areas:

- a) Application of the Business Strategy Driven IT Systems and IT Route Map approach to other manufacturing domains.
- b) Generation of process models to support other global business development strategies.
- c) Development of low cost systems architectures
- d) Provision of a computer based tool to support IT Route Map processes.
- e) Requirements analysis and planning for the creation of public domain repositories

13.3.1 Application of the Business Strategy Driven IT Systems and IT Route Map approach to other manufacturing domains

The Business Driven Strategy IT Systems concept and IT Route Map approach have been directed solely at the ETO/MTO SME domain. The enterprise engineering methodology employed within this domain is equally applicable to other larger manufacturing enterprises operating different production strategies. Further research and analysis should be conducted to identify and accumulate characteristics and design requirements for other specific industrial domains.

13.3.2 Generation of process models to support other global business development strategies

Due to the primary focus of the research reported within this thesis being concentrated on a case study enterprise undertaking a M&A integration process, additional work should be directed at other global business development strategies. Suggested areas of process decomposition and business support should include sales agent development, knowledge licensing agreements, joint ventures, manufacturing subsidiaries and divestitures.

13.3.3 Development of low cost systems architectures

Within this thesis a number of technological concerns were raised about the availability of low cost, low support, low maintenance and expandable computer systems architectures. These specifically apply to: (1) using more than one computer to share processing loads (2) database mirroring to provide system resilience (3) removal of batch processes to facilitate 24 /7 operational availability and (4) improved latency of systems data transactions to provide more real-time information.

13.3.4 Provision of a computer based tool to support IT Route Map processes

Whilst the IT Route Map procedural steps undertaken within the case study have utilised a number of manual and computer based technique support tools, no singular IT tool is currently available to support the whole process. The development of such a tool is required to cover a full range of IT Route Map aspects for the full enterprise

life-cycle and include systems analysis, systems modelling, business process model representation, model enactment, database design and systems management.

13.3.5 Requirements analysis and planning for the creation of public domain repositories

As a result of the work contained within this thesis it had been realised that the development of Business Driven IT Strategy Systems concepts and the IT Route Map approach, promote and effectively support enterprise model and software component re-use. Based upon the requirement of providing SMEs with low cost manufacturing business systems the notion of a domain repository to provide model / software storage and provision can be seen as a viable way forward. This repository would need to be located within the public domain to reduce costs and be effectively administrated. Research on the full requirements and implementation planning would be a logical step forward to take this thesis work a step closer to realisation.

REFERENCES

- [1] M. Hammer and J. Champy, "Re-engineering the Corporation", Harper Collins, 1993.
- [2] G. Kruse, "Business Process Innovation: A Primer", BPICS Control, Feb/March, 1995, pp27-30.
- [3] F. B. Vernadat, "Enterprise Modelling and Integration: Principles and Applications", Chapman and Hall, 1996.
- [4] P. D. Denton and A. Hodgson, "Systems Development for Global Manufacturing", Proceedings of the 5th International Conference on Factory 2000, IEE, No 435, 1997, pp395-402.
- [5] D. M. Schweiger and P. Very, "International Mergers and Acquisitions Special Issue", Journal of World Business, Vol. 36, No. 1, 2001.
- [6] P. D. Denton and A. Hodgson, "Can SMEs Afford MRP?", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp735-738.
- [7] M. Kennerley and A. Neely, "Enterprise Resource Planning: Analysing the Impact", Journal of Integrated Manufacturing Systems, Vol. 12, No2, 2001, pp103-113.
- [8] D. Ford, "Beyond ERP", IEE, Manufacturing Engineer, Vol. 79, No 5, 2000, pp210-213.
- [9] J. C. Wortmann, "Evolution of ERP Systems", Proceedings of the International Conference of the Manufacturing Value-Chain, Kluwer Academic Publishers, 1998, pp11-23.
- [10] T. H. Davenport, "Putting the Enterprise into the Enterprise System", Harvard Business Review, Jul/Aug, 1998, pp121-131.
- [11] E. Kelller, "Enterprise Resource Planning (ERP): Quantifying the Vision", Gartner Group, 1993.
- [12] M. Evans, S. Bragg and T. Kleevers, "Ovum Evaluates: ERP for Manufacturers", Ovum UK.
- [13] P. D. Denton and A. Hodgson, "Implementing Strategy-Led BPR in a Small Manufacturing Company", Proceedings of the 5th International Conference on Factory 2000, IEE, No 435, 1997, pp1-8.
- [14] J. Y. L. Thong, "Resource Constraints and Information Systems Implementation in Singaporean Small Businesses", The International Journal of Information Science, Vol. 29, No. 2, 2001, pp143-156.
- [15] P. J. Armstrong and P. J. Coyle, "The Relevance of Enterprise Resource Planning to Manufacturing SMEs", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp721-724.
- [16] D. Little, C. J. Gavin, N. Hodgson and D. Guenaoui, "Survey of SME Information Systems Planning and Operation", Institute of Operations Management, Control, Vol. 23, No 5, 1997, pp17-20.

- [17] R. H. Weston, "Steps Towards Enterprise-wide Integration: A definition of needs and first generation open solutions", *International Journal of Production Research*, Vol. 39, No. 9, 1993, pp2235-2254.
- [18] C. J. Gavin and P. Cheshire, "Enterprise-Wide versus Best of Breed Manufacturing Solutions: providing a structured approach to systems strategy selection", *Proceedings of the International Conference of the Manufacturing Value-Chain*, Kluwer Academic Publishers, 1998, pp489-496.
- [19] R. H. Weston, "Enterprise Modelling in Support of Global Manufacturing", *Global Manufacturing Strategy Module - Course Notes*, Loughborough University, 1999.
- [20] J. C. Levy, "Small and Medium Sized Manufacturing Enterprises", IEE, 1993.
- [21] P. G. Ranky, "Manufacturing Database Management and Knowledge Based Expert Systems", CIMware Limited, 1990.
- [22] M. Lanigan, "Engineers in Business: The Principles of Management and Product Design", Addison-Wesley, 1992.
- [23] T. H Davenport, and J. E. Short, "The New Industrial Engineering: Information Technology and Business Process Re-design", *Sloan Management Review*, Summer 1990, pp 11-27.
- [24] O. Wight, "Customer Focus", Oliver Wight Europe, Africa and Middle East, 1996.
- [25] H. J. Warnecke, "The Fractal Company: A Revolution in Corporate Culture", Springer-Verlag, 1993.
- [26] K. M. Delargy, "The New Business Landscape", IEE, *Manufacturing Engineer*, Vol. 80, No. 4, 2001, pp169-173.
- [27] U. Rembold, C. Blume and R. Dillman, "Computer Integrated Manufacturing Technology and Systems", Marcel Dekker Inc, 1985.
- [28] OECD, "Industrial Policy in OECD Countries", *Annual Review*, OECD, 1995, p83.
- [29] J. C. Levy and B. M. Nonhebel, "UK Manufacturing - Sustaining Recovery", IEE, 1995.
- [30] D. Grant, "2015 Vision", IEE, *Manufacturing Engineer*, Vol. 77, No. 5, 1998, pp237-241.
- [31] K. M. Srinivas, "Globalisation of Business and The Third World", *Journal of Management Development*, Vol. 14, No. 3, 1995, pp 26-49.
- [32] K. Ohmae, "Putting Global Logic First", *Harvard Business Review*, Vol. 78, No. 1, 1995, pp 119-125.
- [33] J. C. Levy, "UK Manufacturing - Facing International Change", IEE, 1994.
- [34] K. M. Gardiner, "Globalisation, Integration, Fractal Systems and Dichotomies - A 2020 Vision", *Proceedings of the 8th International FAIM Conference*, Begell House Inc, 1998, pp15-27.
- [35] J. P. Womack, D. T. Jones and D. Roos, "The Machine that Changed the World", Macmillian Books, 1990.
- [36] P. J. Buckley and M. C. Casson, "Models of Multinational Enterprise", *Journal of International Business Studies*, Vol. 29, No. 1, 1998, pp21-44.

- [37] R. E. Caves, "Multinational Enterprise and Economic Analysis", Cambridge University Press, 1996.
- [38] F. Knickerbocker, "Oligopolistic Reaction and Multinational Enterprise", Harvard University Press, 1973.
- [39] M. E. Porter, "Competition in Global Industries", Harvard Business School Press, 1986.
- [40] S. H. Rhinesmith, "An Agenda for Globalisation", Training and Development Journal, Vol. 45, No. 2, 1991, pp 22-29.
- [41] P. Potrandolfo and O. Okogbaa, "Global Manufacturing: A review and framework for planning in a global corporation", International Journal of Production Research, Vol. 37, No. 1, 1999, pp1-19.
- [42] P. Lasserre, "Corporate Strategies for the Asia Pacific Region", Long Range Planning, Vol. 28, No.1, 1995, pp13-30.
- [43] G. Hamel and C. K. Prahalad, "The Core Competence of the Corporation", Harvard Business Review, May/June, 1990, pp79-91.
- [44] M. Z. Brooke, "International Management: A Review of Strategies and Operations", Hutchinson, 1986.
- [45] M. Chateuka and N. D. Burns, "The Design of a Global Organisation: The influence of national culture on the design of global organisation", Proceedings of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and Achievement", Loughborough University, Mechanical Engineering Publications, 1997, pp165-169
- [46] A. Bartmess and K. Cerny, "Building Competitive Advantage through a Global Network of Capabilities", IEE, Engineering Management Review, Vol. 24, No. 2, 1996, pp29-42.
- [47] M. Marquardt and A. Reynolds, "The Global Learning Organisation", Irwin, 1994.
- [48] R.H. Hayes and S. C. Wheelwright, "Restoring our Competitive Advantage: Competing through Manufacturing", John Wiley & Sons, 1985.
- [49] R. J. Schonberger, "World Class Manufacturing - The Lessons of Simplicity Applied", The Free Press, 1986.
- [50] J. Todd, "World Class Manufacturing", McGraw Hill, 1994.
- [51] T.G. Gunn, "Manufacturing for Competitive Advantage: Becoming a world class manufacturer", Ballinger Publishing, 1987.
- [52] "Managing into the 90s - Manufacturing", Department of Trade and Industry, 1990.
- [53] "Managing into the 90s - Aiming for World Class Manufacturing", Department of Trade and Industry, 1991.
- [54] Department of Trade and Industry and Cranfield School of Management, "Management Today's Guide to Britain's Best Factories", Management Today, Vol. 2, 1996.
- [55] B. B. Flynn, R. G. Schroeder, E. J. Flynn, S. Sakaibara, and K. A. Bates, "World Class Manufacturing Project: Overview and selected results", International Journal of Operations and Production Management, Vol. 17, No. 7, 1997, pp671-685.

- [56] L. C. Hendry, "World Class in the Make-To-Order Sector", Proceedings of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and Achievement", Loughborough University, Mechanical Engineering Publications, 1997, pp41-46.
- [57] P. Burcher and K. Stevens, "Measuring up to World Class Manufacturing", BPICS, Control, Vol. 22, No. 1, 1996, pp17-21.
- [58] M. E. Porter, "Competitive Strategy", Macmillan, 1980.
- [59] M. E. Porter, "Competitive Advantage", Macmillan, 1985.
- [60] N. Burns, "Manufacturing Business Systems", Manufacturing Business Systems Module - Course Notes, Loughborough University, 1994.
- [61] K. Chaharbaghi and E. Nugent, "Sustainable Competitive Advantage in Perspective", IEE, Engineering Management, Vol. 6, No. 1, 1996, pp13-16.
- [62] G. L. Parsons, "Information Technology a New Competitive Weapon", Sloan Management Review, 1983.
- [63] R. D. Galliers, "Information Systems and Technology Planning in a Competitive Strategy Framework", Information Management in Competitive Success, Pergamon Infotech Limited, 1986, pp 37-51.
- [64] B. Ives and G. P. Learmouth, "The Information System as a Competitive Weapon", Communications of the ACM, Vol. 27, No. 12, 1984, pp 1193-1201.
- [65] J. I. Cash and B. R. Konsynski, "IS Redraws Competitive Boundaries", Harvard Business Review, Vol. 63, No. 2, 1985, pp 134-142.
- [66] W. J. Kettinger, V. Groover and A. H. Segars, "Do Strategic Systems Really Pay Off ?", Information Systems Management, Vol. 12, No. 1, 1995, pp 35-43.
- [67] I. Roberts, "BPR for SMEs", IEE, Manufacturing Engineer, Vol. 76, No. 6, 1997, pp261-263.
- [68] J. W. Lu and P. W. Beamish, "The Internationalisation and Performance of SMEs", Strategic Management Journal, Vol. 22, Jun/Jul, 2001, pp565-586.
- [69] X. Huang and A. Brown, "An Analysis and Classification of Problems in Small Business", International Small Business Journal", Vol. 18, No.1, 2000, pp73-85.
- [70] D. Smith, "Small Business Research Programme", Interim Review, ESRC, 1993.
- [71] J. Bridge and M. J. Peel, "A Study of Computer Usage and Strategic Planning in the SME Sector", International Small Business Journal", Vol. 17, No.4, 1999, pp82-87.
- [72] P. Burton, "The Widebeam Project: ITC for Engineering and Manufacturing", IEE, Engineering Management, Vol. 10, No. 1, 2000, pp29-37.
- [73] C. E. Pollard and S. C. Hayne, "The Changing Face of Information Systems in Small Firms", International Small Business Journal", 1998, Vol. 16, No.3, pp70-87.
- [74] P. Mileham, "Boardroom Leadership: Do small and medium sized companies need non-executive directors", Journal of General Management, Vol. 22, No.1, 1996, pp14-27.
- [75] N. Clay and N. Cowling, "Small Firms and Bank Relationships", International Journal of Management Science, Vol. 24, 1995, pp115-120.

- [76] Bank of England, "Bank Lending to Smaller Businesses", The Bank of England, 1993.
- [77] M. Binks, C. Ennew and G. Reed, "Small Businesses and Their Banks", Forum of Private Business, 1990.
- [78] M. Hammer and S. A. Stanton, "The Re-engineering Revolution Handbook", Harper Collins, 1996.
- [79] K. Foddy, "BPR: No Pain, No Risk, No Kidding", Engineering Computers, Vol. 13, 1994, pp27-31.
- [80] J. Bridge and M. J. Peel, "A Study of Computer Usage and Strategic Planning in the SME Sector", International Small Business Journal, Vol. 17, No. 4, 1998, pp82-87.
- [81] M. Hammer, "Re-engineering Work: Don't Automate, Obliterate", Harvard Business Review, 1990, Jul/Aug.
- [82] H. D. Haustein, H. Maier, and J. Robinson, "Thinking About Appropriate Technology", Criteria for Selecting Appropriate Technologies under Different Cultural, Technical and Social Conditions, Pergamon Press, 1979, pp 25-36.
- [83] R. S. A. Al-Thiga, "Technology Transfer: What to Transfer?", Criteria for Selecting Appropriate Technologies under Different Cultural, Technical and Social Conditions, Pergamon Press, 1979, pp 21-24.
- [84] J. F. Rada, "Information Technology and Developing Countries", Systems Approach to Appropriate Technology Transfer, Pergamon Press, 1982, pp 39-50.
- [85] J. Bennett, M. Polkinghorne and J. Pearce, "Teaching Company Scheme: Technology Transfer for SMEs", Manufacturing Engineer, IEE, Vol. 77, No. 3, 1998, pp139-143.
- [86] "TCS Annual Report 2000/2001", UK Teaching Company Directorate, 2001.
- [87] P. Fleissner, "Preface", Systems Approach to Appropriate Technology Transfer, Pergamon Press, 1982.
- [88] A. Harrison and J. Storey, "New-Wave Manufacturing Strategies: Operational, organisational and human dimensions", International Journal of Operations and Production Management, Vol. 16, NO. 2, 1996, pp63-76.
- [89] J. Storey (Ed), "New-Wave Manufacturing Strategies", Paul Chapman, 1994.
- [90] C. A. Voss, (Ed), "Manufacturing Strategy, Process and Content", Chapman and Hall, 1992.
- [91] P. Foyer, "A Manufacturing Strategy", IEE, Manufacturing Engineer, Vol. 73, No. 4, 1994, p 152.
- [92] J. A. Pearce and R. B. Robinson, "Strategic Management: Strategy Formulation and Implementation", Irwin, 1988.
- [93] A. L. Inquinto and J. W. Fredrickson, "Top Management Team Agreement about the Strategic Decision Process: A test of some of its determinants and consequences", Strategic Management Journal, Vol. 18, No. 1, 1997, pp63-75.
- [94] A. J. Ward, "Implementing Employee Empowerment", Information Systems Management, Vol.14, No.1, 1997, pp62-65.

- [95] D. W. Karger, and Z. A. Malik, "Long Range Planning and Organisational Performance", Long Range Planning, Dec, 1975, pp 60-64.
- [96] R. M. Fulmer and L. W. Rue, "The Practice and Profitability of Long Range Planning", Managerial Planning, Vol. 22, 1974, pp 1-7.
- [97] P. F. Schlesinger, V. Sathe, L. A. Schlesinger, and J. P. Kotter, "Organisation", Irwin, 1992.
- [98] J. McCalman, and R. A. Paton, "Change Management", Paul Chapman Publishing, 1992.
- [99] G. H. Huang and K. L. Mak, "Current Practices of Engineering Change Management in UK Manufacturing Industries", International Journal of Operations and Production Management, Vol. 19, No. 1, 1999, pp21-37.
- [100] F. Nortier, "A New Angle with Coping with Change: Transition management", Journal of Management Development, Vol. 14, No.4, 1995, pp32-46.
- [101] J. P. Kotter, "Leading Change: Why transformation efforts fail", Harvard Business Review, Vol. 73, No. 2, pp59-67.
- [102] "Survey of Manufacturing: Meet the Global Factory", IEEE, Engineering Management Review", Vol.27, No.1, 1999, pp12-26.
- [103] G. Hamel and C. K. Prahalad, "Competing for the Future", Harvard Business School Press, 1994.
- [104] P. F. Drucker, "The Practice of Management", Harper and Row, 1954.
- [105] K. O. Magnasen, "Organisational Design, Development and Behaviour", Scott, Foresman and Company, 1977.
- [106] "Information Technology Management in a Merger and Acquisition Strategy Report", Compass America, 2000.
- [107] "IT Services Mergers and Acquisitions: An executive primer focus report", Gartner Group, 2000.
- [108] J. Kelly and C. Cook, "Mergers and Acquisitions: A global research report", KPMG Consulting, 1999.
- [109] B. Zrimsek, "Mergers, Acquisitions, Divestitures and Application Portfolios", Gartner Group, 2001.
- [110] C. Berry, "Mergers Management: Acquiring Skills", IEE, Manufacturing Engineer, Vol. 78, No. 2, 1999, pp73-75.
- [111] J. Bleeke and D. Ernst, "Is Your Strategic Alliance Really a Sale?", Harvard Business Review, Jan-Feb, 1995, pp97-105.
- [112] G. Ming-Hong Lai, "Knowing Who You Are Doing Business With In Japan: A managerial view of Keiretsu and Keiretsu Business Groups", Journal of World Business, Vol. 34, No.4, 1999, pp423-448.
- [113] P. D. Denton, A. Hodgson and I. A. Hreczuk-Hirst, "Implementing Intranet Support for BPR in a Small Manufacturing Company", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp739-742.

- [114] F. Hewitt, "Business Process Innovation in the Mid-1990s", *Integrated Manufacturing Systems*, Vol. 6, No. 2, 1995, pp18-26.
- [115] M. Broadbent, P. Weil and D. St. Clair, "The Implication of IT Infrastructure for Business Process Re-design", *MIS Quarterly*, Vol. 23, No. 2, 1999, pp159-182.
- [116] R. E. Miles, H. J. Coleman and W.E. Douglas-Creed, "Keys to Success in Corporate Re-design", *IEE, Engineering Management Review*, Vol. 25, No. 1, 1997, pp5-15.
- [117] W. J. Kettinger and V. Grover, "Toward a Theory of Business Process Change Management", *Journal of Management Information Systems*, Vol. 12, No. 1, 1995, pp9-30.
- [118] P. Seltsikas, "Information Management in Process-Based Organisations", *Information Systems Journal*, Vol. 9, 1999, p181-195.
- [119] F. S. Settles, "Business Process Re-engineering: Current Issues and Applications", *Industrial Engineering and Management Press*, 1993.
- [120] B. Wu, J. M. Kay and V. Looks, "Business Process Development - A Methodology for the Convergence of Business Systems", *Proceedings of the 15th International Conference on Production Research*, Vol. 1, 1999, pp713-716.
- [121] A. Gurton, "Business Process Re-engineering: Better than Before?", *Personal Computer Magazine*, Feb, 1995, pp170-176.
- [122] G. A. Pall, "Quality Process Management", *Prentice-Hall*, 1987.
- [123] T. H. Davenport, "Process Innovation", *Harvard Business School Press*, 1993.
- [124] P. B. Crosby, "Quality is Free", *New America Library*, 1979.
- [125] K. Foddy, "Business Process Re-engineering: No pain, No risk, No kidding", *Engineering Computers*, Vol. 13, No. 2, 1994, pp27-31.
- [126] M. Kutschker, "Re-engineering of Business Processes in Multi-national Corporations", *University of Eichstatt - Germany, Working Paper No. 95-4*,
<http://www.gsia.cmu.edu/bosch/kut.html>
- [127] J. Lyu, "Applying Kaizen and Automation to Process Re-engineering", *Journal of Manufacturing Systems*, Vol. 15, No. 2, 1996, pp125-132.
- [128] J. T. C. Teng, V. Grover and K. D. Fielder, "Developing Strategic Perspectives on Business Process Re-engineering: From process re-configuration to organisational change", *International Journal of Management Science*, Vol. 24, No. 3, 1996, pp271-294.
- [129] T. A. Stewart, "US Productivity: First but Fading", *Fortune Magazine*, May 18th, 1992.
- [130] S. Sarker and A. S. Lee, "IT-enabled Organisational Transformation: A case study of BPR failure at Telecom", *Journal of Strategic Information Systems*, Vol. 8, No. 1, 1999, pp83-103.
- [131] T. Guimaraes and W. Bond, "Empirically Assessing the Impact of BPR on Manufacturing Firms", *International Journal of Operations and Production Management*, Vol. 16, No. 8, 1996, pp5-28.
- [132] Innovative Manufacturing Initiative (IMI), "Business Process Re-engineering Report", *MSI Research Institute, Loughborough University*,
http://msiri.lboro.ac.uk/publications/imi_bpr/bprmain.html

- [133] M. Alavi and Y. Yoo, "Productivity Gains of BPR", *Information Systems Management*, Vol. 12, No. 4, 1995, pp43-47.
- [134] T. Guimaraes, "Field Testing the Proposed Predictors of BPR Success in Manufacturing Firms", *Journal of Manufacturing System*, Vol. 18, No. 1, 1999, pp53-65.
- [135] I. Roberts, "BPR for SMEs", *IEE, Manufacturing Engineer*, Vol. 76, No. 6, 1997, pp261-263.
- [136] S. Corrigan, "Human and Organisational Aspects of Business Process Re-engineering", *ESRC Business Process Resource Centre*, University of Warwick.
- [137] W. H. Davidson, "Beyond Re-engineering: The three phases of business transformation", *IEE, Engineering Management Review*, Vol. 23, No. 2, 1995, pp17-26.
- [138] K. Kosanke, F. B. Vernadat and M. Zelm, "CIMOSA: Enterprise Engineering and Integration", *Computers in Industry*, Vol.40 No. 2/3, 1999, pp83-97.
- [139] H. Rozenfeld, A. F. Rentes and W. Konig, "Workflow Modelling for Advanced Manufacturing Concepts", *Annals of CIRP*, Vol. 43, No. 1, 1994, pp385-388.
- [140] C. Kim, R. Weston and H. Woo, "Development of an Integrated Methodology for Enterprise Engineering", *International Journal of Computer Integrated Manufacturing*, Vol. 14, No. 5, 2001, pp473-488.
- [141] J. M. Edwards, M. Wilson, C. Aguiar and I. A. Coutts, "A Top Down and Bottom Up Approach to Manufacturing Enterprise Engineering Using the Function View", *International Journal of Computer Integrated Manufacturing*, Vol. 11, No. 4, 1998, pp364-376.
- [142] K. Kosanke, and J. G. Nell (Eds), "Enterprise Engineering and Integration", Springer-Verlag, 1997.
- [143] K. Kosanke, F. Vernadat and M. Zelm, "Editorial", *Computers in Industry*, Vol. 40, No.2-3, 1999, pp79-81.
- [144] P. Bernus and L. Nemes, "A Framework to Define a Generic Enterprise Reference Architecture and Methodology", *Computer Integrated Manufacturing Systems*, Vol. 9, No. 3, 1996, pp179-191.
- [145] G. Billing and M. Mauderer, "Integrated Planning and Development of Manufacturing Systems", *Proceedings of the 15th International Conference on Production Research*, Vol. 1, 1999, pp315-318.
- [146] T. Baines, R. Greenough and J. Ladbrook, "Modelling the Resource We Call Human", *IEE, Manufacturing Engineer*, Vol. 78, No. 6, 1999, pp255-259.
- [147] L. E. Davis, "Organisational Design", *Handbook of Industrial Engineering*, Wiley and Sons, 1982.
- [148] R. H. Weston, "Re-configurable, Component Based Systems and the Role of Enterprise Engineering Concepts", *Computers in Industry*, Vol. 40, No.2/3, 1999, pp321-343.
- [149] C. Handy, "The Age of Unreason", Arrow Books, 1992.
- [150] C. Handy, "Understanding Organisations", Penguin, 1993.

- [151] R. H. Weston, P. E. Clements, N. D. Shorter, A. J. Carrott, A. Hodgson and A. A. West, "On The Explicit Modelling of Systems of Human Resources", *International Journal of Production Research*, Vol. 39, No. 2, 2001, pp184-204.
- [152] M. W. C. Aguiar and R. H. Weston, "A Model-Driven Approach to Enterprise Integration", *International Journal of Computer Integrated Manufacturing*, Vol. 8, No. 3, 1995, pp210-224.
- [153] K. Kosanke, M. Mollo, F. Naccari and C. Reyneri, "Enterprise Engineering with CIMOSA - Application at Fiat", *Integrated Manufacturing Systems Engineering*, Chapman Hall, 1995, pp31-45.
- [154] E. Lutherer, M. Martinez, J. Farvel and B. Querenet, "Towards a CIM Engineering Workbench", *Proceedings of the European Workshop on Integrated Manufacturing Systems*, 1994, pp79-85.
- [155] D. T. Wright and A. J. Clegg, "Towards Sustainable Virtual Enterprises", *Proceeding of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and Achievement*, Loughborough University, Mechanical Engineering Publications, 1997, pp419-424.
- [156] W. Shin, "Manufacturing in Networks - Competitive Advantage for Virtual Enterprises", *Proceedings of the International Conference of the Manufacturing Value-Chain*, Kluwer Academic Publishers, 1998, pp249-357.
- [157] J. Browne, P. Sackett and H. Wortmann, "Industry Requirements and Associated Issues in the Extended Enterprise", *Integrated Manufacturing Systems Engineering*, Chapman Hall, 1995, pp13-28.
- [158] Z. Deng, B. Bang, A. Laksa and S. Nadarajah, "A Model of Enterprise Integration and Collaboration Tools and Communication Infrastructure for Inter-Enterprise Collaboration", *Proceedings of the 10th International IFIP WG 5.2/5.3 Conference - Prolamat 98*, 1998, No. 18.
- [159] W. Shen and D. H. Norrie, "An Agent-Based Approach for Manufacturing Enterprise Integration and Supply Chain Management", *Proceedings of the 10th International IFIP WG 5.2/5.3 Conference - Prolamat 98*, 1998, No. 94.
- [160] R. H. Weston, "Model-Driven Configuration and Information Sharing in Concurrent Engineering", *Annals of the CIRP*, Vol. 45, No. 1, 1996, pp449-454.
- [161] K. T. K. Toh, "The Realisation of Reference Enterprise Modelling Architectures", *International Journal of Computer Integrated Manufacture*, Vol. 11, 1998.
- [162] V. Singh, "The CIM Debacle: Methodologies to facilitate software interoperability", Springer-Verlag, 1997.
- [163] CEN, "ENV 40 003: Computer Integrated Manufacturing: Systems Architecture Framework for Enterprise Modelling", CEN/CENLEC, Brussels, 1990.
- [164] AMICE, "CIMOSA: Open System Architecture for CIM", Springer-Verlag, 1993.
- [165] IMPACT, "Esprit No. 2165", *Proceedings of the Workshop*, Berlin, 1991.

- [166] F. Kimura, "Software for Product Realisation", International Symposium for International Trends in Manufacturing Towards the 21st Century, Berlin 1991.
- [167] G. Berio and F. B. Vernadat, "New Developments in Enterprise Modelling Using CIMOSA", Computers in Industry, Vol. 40, No. 2-3, 1999, pp99-114.
- [168] N. E. Ozdemirel, G. Y. Yurttas and G. Koksai, "Computer-Aided Planning and Design of Manufacturing Simulation Experiments", Journal of Simulation, Vol. 63, No. 3, 1996, pp171-191.
- [169] K. Popplewell, "Factory Modelling and Simulation of Manufacturing Systems", Proceeding of the First International Conference on Responsive Manufacturing, University of Nottingham, pp71-81.
- [170] R. Smeds, "Developing the Manufacturing Value Chain through Simulation: The Finnish Enterprise Simulation Laboratory Project", in Strategic Management of the Value Chain, Kluwer Academic Publishers, 1998, pp535-543.
- [171] J. J. Van Griethuysen, "Enterprise Modelling: A necessary basis for modern information systems", Open Distributed Processing, Elviesier Science Publishers, 1992.
- [172] A. G. Molina, "A Manufacturing Model to Support Data-Driven Applications for Design and Manufacture", PhD Thesis, Loughborough University, 1995.
- [173] D. S. Coleman, "A Framework for Characterising the Methods and Tools of an Integrated System Engineering Methodology (ISEM)", Pacific Information Management, Draft 2, Rev 0, 1989, p2.
- [174] D. T. Ross, "'Structured Analysis (SA): A language for communicating ideas", IEEE, Transactions on Software Engineering, Vol. 3, 1977, pp6-15.
- [175] P. T. Ward and S. J. Mellor, "Structured Development for Real-time Systems", Prentice-Hall, 1985.
- [176] A. W. Scheer, "Enterprise Wide Data Modelling", Information Systems in Industry, Springer-Verlag, 1989.
- [177] D. Schenck and P. Wilson, "Information Modelling the Express Way", Oxford University Press, 1994.
- [178] J. Klein and A. D. Scheer, "Information Modelling: The basis for integrated information systems", Workshop Implementing CIM, Saabruken, Germany, 1990.
- [179] C. M. Eastman, "The Contribution of Data Modelling to the Future Development of CAD/CAM Databases", Proceedings of the ASME International Computers in Engineering Conference, California, 1991, pp49-54.
- [180] T. DeMarco, "Structured Analysis and System Specification", Yourdon Press - Prentice Hall, 1979.
- [181] P. P. Chen, "The Entity Relationship Model: Towards a unified view of data", ACM Transactions on Database Systems, Vol. 1, No. 1, 1976, pp9-36.
- [182] D. Appleton, "Information Modelling Manual", D. Appleton Co., 1985.

- [183] G. Verheijen and J. VanBekkum, "NIAM: An information analysis method", Information Systems Design Methodology, Verrijn-Stuart, 1982.
- [184] H. C. Smith, "Database Design: Composing fully normalised tables from a rigorous dependency diagram", communications of the ACM, Vol. 28, No.8, 1985.
- [185] ISO DIS 10303-11, "Express Language Reference Manual", International Standards Organisation, 1993.
- [186] J. S. Busby and G. M. Williams, "The Value and Limitations of Using Process Models to Describe the Manufacturing Organisation", International Journal of Production Research, Vol. 31, No. 9, 1993, pp2179-2194.
- [187] R. R. Bravoco and S. B. Yadav, "Requirement Definition Architecture: An overview" Computers in Industry, Vol. 6, 1985, pp237-251.
- [188] R. R. Bravoco and S. B. Yadav, "A Methodology to Model the Functional Structure of an Organisation", Computers in Industry, Vol. 6, 1985, pp345-361.
- [189] R. L. Mayer, C. P. Menzel and P. S. D Mayer, "IDEF3 Technical Report", Knowledge Based Systems Laboratory, Texas A&M, 1990.
- [190] IPAD, "Integrated Information Processing Requirements (D6-IPAD-70040-D)", Development of Integrated Programs for Aerospace-Vehicle Design (IPAD), NASA, June, 1977.
- [191] IPAD, "Integrated Information Processing Requirements (D6-IPAD-70040-D)", Development of Integrated Programs for Aerospace-Vehicle Design (IPAD), NASA, December, 1977.
- [192] M. Kinstrey, V. K. Lee, J. W. Lewis, E. L. Salant, B. D. Sarachan and P. R. Wilson, "PPO Management", Proceedings on the 2nd National Symposium on Concurrent Engineering, Morgantown, US, 1990, pp67-90.
- [193] S. Czernik and W. Quint, "Selection of Methods, Techniques and Tools for System Analysis and Design for the Integration of CIM Elements in Existing Manufacturing Organisations", Production Planning and Control, Vol. 3, No. 2, 1992, pp202-209.
- [194] T. Murata, "Petri-Nets: Properties, analysis and applications", Proceedings of the IEEE, Vol. 77, No. 4, 1989, pp541-580.
- [195] F. DiCesare, G. Harhalajis, J-M. Proth, M. Silva and F. B. Vernadat, "Practice of Petri Nets in Manufacturing", Chapman and Hall, 1993.
- [196] T. Amble, "Logic Programming and Knowledge Engineering", Addison-Wesley, 1987.
- [197] J. F. Sowa, "Conceptual Structures: Information processing in mind and machine", Addison-Wesley, 1984.
- [198] A. Hodgson, "The Application of Conceptual Graphs to Standards-Based intelligent Integration of Manufacturing Enterprises", International Conference on Factory 2000", IEE, Conference Publication No. 398, 1994, pp154-161.
- [199] G. Booch, "Object-oriented Design with Applications", Benjamin Cummings, 1991.
- [200] P. Coad and E. Yourdon, "Object-oriented Analysis", Prentice-Hall, 1990.

- [201] D. T. Ross, "Applications and Extensions of SADT", Computer, Vol. 18, No. 4, 1985, pp25-34.
- [202] C. Petrie (Ed), "Enterprise Integration Modelling", The MIT Press, Cambridge, MA, 1992.
- [203] M. Uschold, M. King, S. Moralee and Y. Zorgios, "The Enterprise Ontology", The Knowledge Engineering Review, Vol. 13, Special Issue on Putting Ontologies to Use.
- [204] M. Fox, J.F. Fadel and F. G. Fadel, "A Common Sense Model of the Enterprise", Proceedings of the Third Industrial Engineering Research Conference, Norcross, GA, 1993, pp425-429.
- [205] Artificial Intelligence Applications Institute, University of Edinburgh, "The Enterprise Project", <http://www.aiai.ed.ac.uk/~entprise/enterprise/ontology.htm>
- [206] R. J. Mayer, T. P. Cullinane, P. S. DeWitte, W.B. Knappenberger, B. Perakath and M. S. Wells, "Information Integration for Concurrent Engineering IDEF3 Process Description Capture Report", Armstrong Laboratory, Wright-Patterson, AI-TR-1992-0057, 1992.
- [207] ICAM, "US Air Force Integrated Computer Aided Manufacturing (ICAM) Architecture", Air Force Materials Laboratory, Vol. 4, Part. 2, 1981.
- [208] T. J. Williams, "The Purdue Enterprise Reference Architecture", Instrument Society of America, Research Triangle Park, 1992.
- [209] T. J. Williams, "The Purdue Enterprise Reference Architecture", Computers in Industry, Vol. 24, No. 2-3, 1994, pp141-158.
- [210] CIMOSA Association, "CIMOSA Formal Reference Base", Ver. 3.2, CIMOSA Association, Germany, 1996.
- [211] G. Doumeingts, B. Vallespir, M. Zanettin and D. Chen, "GIM, GRAI Integrated Methodology: A methodology for designing CIM systems", Version 1.0, Unnumbered Report, LAP/GRAI, University of Bordeaux, 1992.
- [212] B. Vallespir, D. Chen, M. Zanettin and G. Doumeingts, "Definition of a CIM System Architecture within the ESPRIT Project IMPACS", Computer Applications in Production Engineering: Integration Aspects, Amsterdam, 1991, pp731-738.
- [213] D. Chen, B. Vallespir and G. Doumeingts, "GRAI Integrated Methodology and its Mapping onto Generic Enterprise Reference Architecture and Methodology", Computers in Industry, Vol. 33, 1997, pp387-394.
- [214] A. W. Scheer, "Architecture of Integrated Information Systems: Foundations of Enterprise Modelling", Springer-Verlag, 1992.
- [215] A. W. Scheer, "Business Process Re-engineering: Reference models for industrial enterprises", Springer-Verlag, 1994.
- [216] A. W. Scheer and G. Kruse, "ARIS Framework and Toolset: A Comprehensive Business Process Re-engineering Methodology", Proceedings on the Third International Conference on Automation, Robotics and Computer Vision, 1994, pp327-337.

- [217] T. J. Williams, "Development of GERAM: A generic enterprise reference architecture integration methodology", Integrated Manufacturing Systems Engineering, Chapman and Hall, 1995.
- [218] "GERAM: Generalised Enterprise Reference Architecture and Methodology", Ver 1.5, IFAC-IFIP Task Force on Enterprise Integration, 1997.
- [219] D. Shorter, "An Evaluation of CIM Modelling Constructs", Computers in Industry, Vol. 24, 1994, pp159-236.
- [220] K. Mertins, W. Sussenguth and R. Jochem, "An Object Oriented Method for Integrated Enterprise Modelling as a Basis for Enterprise Co-ordination", in Enterprise Integration Modelling: Proceedings of the First International Conference, C. J. Petrie (Ed), The MIT Press, Cambridge, MA, pp249-258.
- [221] M. Fox, "The TOVE Project: Towards a common-sense model of the enterprise", in Enterprise Integration Modelling: Proceedings of the First International Conference, C. J. Petrie (Ed), The MIT Press, Cambridge, MA, pp310-319.
- [222] U. Graefe and A. W. Chan, "An Enterprise Model as a Design Tool for Information Infrastructure", Proceedings of the JSPE/IFIP Tc5/WG5.3 Workshop on the Design of Information Infrastructure Systems for Manufacturing, Tokyo, North-Holland, 1993, pp183-192.
- [223] K. T. K. Toh, S. T. Newman and R. Bell, "The Capture of Information Requirements to Support Information Specification in Small Companies", Proceedings of the International Conference on Enterprise Integration and Modelling Technology, Springer, 1997, pp510-520.
- [224] K. T. K. Toh, S. T. Newman and R. Bell, "An Information Systems Architecture for Small Metalworking Companies", Proceedings of the ImechE, Part B, Journal of Engineering Manufacture, Vol. 212, 1998, pp87-103.
- [225] K. T. K. Toh, S. T. Newman and R. Bell, "An Architecture for Information Specification Based on an SME Enterprise Model", Proceedings of the 5th International Conference on Factory 2000, IEE, No 435, 1997, pp456-463.
- [226] M. Cantemessa and E. Paolucci, "Using Organisational Analysis and IDEF0 for Enterprise Modelling in SMEs", International Journal of Computer Integrated Manufacturing, Vol. 11, No. 5, 1998, pp416-429.
- [227] P. Bernus, L. Nemes and T. J. Williams (eds), "Architectures for Enterprise Integration", Chapman and Hall, 1996.
- [228] F. Bonfatti, P. D. Monari and R. Montanari, "Information Flows and Processes in a SME Network", Proceedings of the OE/IFIP/IEEE International Conference on Integrated and Sustainable Production, Chapman and Hall, pp87-98.
- [229] R. Burkhart, "Process-Based Definition of Enterprise Models" in Enterprise Integration Modelling: Proceedings of the First International Conference, C. J. Petrie (Ed), The MIT Press, Cambridge, MA, pp230-238.

- [230] R. J. Mayer and M. K. Painter, "Roadmap for Enterprise Integration", Proceedings of the AUTOFACT'91 Conference, Chicago, SME, 1991, pp1-26.
- [231] T. J. Williams, P. Bernus, J. Brosvic, D. Chen, G. Doumeingts, L. Nemes, J. Vlietstra and S. Zoetekouw, "Architectures for Integrating Manufacturing Activities and Enterprises", Proceedings of the JSPE/IFIP Tc5/WG5.3 Workshop on the Design of Information Infrastructure Systems for Manufacturing, Tokyo, North-Holland, 1993, pp3-18.
- [232] A. W. Scheer, "CIM: Towards the Factory of the Future", Springer-Verlag, 1991.
- [233] N. A. Schofield, "The Development of a Strategy for Integrated Manufacturing Systems", The Institution of Production Engineers, 1990.
- [234] P. Deasley, "Integration: A Way of Life, Work and Education", IEE, Manufacturing Engineer, Vol. 73, No. 5, 1994, pp 209-213.
- [235] G. Robinson, "RSA: The Networked Society for the Arts, Manufacturers and Commerce", RSA Journal, Vol. 140. 1992.
- [236] W. C. Hanson, "The Integrated Enterprise", in Manufacturing Systems: Foundations of World Class Practice, National Academy Press, 1992, pp158-165.
- [237] H. Mintzberg, "The Structuring of Organisations", Prentice-Hall, 1979.
- [238] R. H. Weston, "Steps Towards Enterprise-wide Integration: A definition of needs and first generation open solutions", International Journal of Production Research, Vol. 39, No. 9, 1993, pp2235-2254.
- [239] ESPRIT Consortium, "Open System Architecture for CIM", Project 688, Vol. 1, Springer-Verlag, 1989, pp13-16.
- [240] J. P. Santos, J. J. Ferrira and J. M. Mendonca, "Integrating Infrastructures for Manufacturing a Comparative Analysis", Proceedings of the OE/IFIP/IEEE International Conference on Integrated and Sustainable Industrial Production, Lisbon, Chapman and Hall, 1997.
- [241] OSF, "Introduction to OSF DCE", Prentice-Hall, 1994.
- [242] OMG, "The Common Object Request Broker: Architecture and Specification (CORBA)", Revision 1.2, OMG Document 93-12-43, Object Management Group Inc, 1993.
- [243] S. A. Koubias and G. D. Papadopoulos, "Modern Field Bus Communication Architectures for Real-time Industrial Applications", Computers in Industry Vol. 26, 1995, pp243-252.
- [244] Esprit Project 7096, "CIME Computing Environment Integrating a Communications Network for Manufacturing Applications (CCCE-CNMA)", 1994.
- [245] M. Norrie, M. Wunderli, R. Montau, U. Leonhardt, W. Schaad and H. J. Schek, "Co-ordination Approaches for CIM", In Integrated Manufacturing Systems Engineering, Chapman and Hall, 1995, pp221-235.
- [246] R. Neches, R. Fikes, T. Finn, T. Gruber, R. Patil, T. Senator and W. R. Swartout, "Enabling Technology for Information Sharing", A.I. Magazine, Vol. 12, No. 3, 1991, pp36-56.
- [247] R. H. Weston, J. D. Gascoigne, A. Rui, A. Hodgson, C. M. Sumpter and I. A. Coutts, "Steps Towards Information Integration in Manufacturing", International Journal of Computer Integrated Manufacturing, Vol. 1, No. 3, p140.

- [248] P. Clements, I. A. Coutts and R. H. Weston, "A Life Cycle Support Environment Comprising Open Systems Manufacturing Modelling Methods and the CIM-BIOSYS Infra-structural Tools", Proceedings of the Symposium on Manufacturing Application Programming Language Environment (MAPLE) Conference, Ottawa, pp181-195.
- [249] B. Querenet, "CIMOSA: A European Development for Enterprise Integration. Part III: Enterprise Integrating Infrastructure", In Enterprise Integration Modelling, The MIT Press, Cambridge, MA, 1992, pp205-215.
- [250] P. Pleinevaux, "Integration of Industrial Applications: The CCE-CNMA Approach", In Integrated Manufacturing Systems Engineering, Chapman and Hall, 1995, pp236-247.
- [251] D. Solte, "A Software Engineering Paradigm as a Basis for Enterprise Integration in (Multi-) Client/Server Environments", In Integrated Manufacturing Systems Engineering, Chapman and Hall, 1995, pp248-261.
- [252] J. M. Tenebaum, J. C. Weber and T. Gruber, "Enterprise Integration: Lessons from SHADE and PACT", In Integrated Manufacturing Systems Engineering, Chapman and Hall, 1995, pp356-369.
- [253] CEN, "Tutorial and Evaluation report: Framework and Requirements for Enterprise Model Executions and Integration Services; Part 1: Tutorial", N11.1, CEN TC 310/WG1, European Committee for Standardisation, Brussels, 1993.
- [254] CEN ENV xxx, "Advanced Manufacturing Technology: Systems Architecture - Enterprise Model Execution and Integration Services", CEN TC 310/WG1, European Committee for Standardisation, Brussels, 1998.
- [255] G. Uppington and P. Bernus, "Assessing the Necessity of Enterprise Change: Pre-feasibility and feasibility studies in enterprise integration", International Journal of Computer Integrated Manufacturing, Vol. 11, No. 5, 1998, pp430-447.
- [256] T. Kaihara, "Supply Chain Management with Market Economics", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp659-662.
- [257] K. Tanskanen and A. Hameri, "The Role of Time Variability in Supply Chains: A multiple case study", Proceedings of the International Conference of the Manufacturing Value-Chain, Kluwer Academic Publishers, 1998, pp331-342.
- [258] M. L. Fisher, "Making Supply Meet Demand in the Uncertain World", Harvard Business Review, May/June, 1994.
- [259] G. Kruse, "Meeting Your Customers' Needs: Effective Business Processes for Your Supply Chain", KPMG Consulting, 2000.
- [260] R. Mason-Jones, B. Naylor and D. R. Towill, "Lean, Agile or Leagile: Matching your supply chain to the marketplace", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp593-596.
- [261] R. Hieber, D. Brutsch and F. Frigo-Mosca, "How to Manage your Supply Network to Get Better Results", Proceedings of the International Conference of the Manufacturing Value-Chain, Kluwer Academic Publishers, 1998, pp290-296.

- [262] D. Towill, "The Seamless Supply Chain - The predator's strategic advantage", *International Journal of Technology Management*, Vol. 13, No. 1, 1996, pp37-56.
- [263] N. J. O'Connor, "Supply Chain Competition", *IEE, Manufacturing Engineer*, Vol. 76, No. 4, 1997, pp183-185.
- [264] D. J. Bowersox and D. J. Closs, "Logistical Management", McGraw-Hill, 1996.
- [265] J. Browne and P. Jordan, "A Structured Approach to Performance Measurement and Benchmarking for Manufacturing Enterprises", *Proceedings of the International Conference of the Manufacturing Value-Chain*, Kluwer Academic Publishers, 1998, pp2172261-342.
- [266] R. P. Van Amstel and G. D'hert, "Performance Indicators in Distribution", *The International Journal of Logistics Management*, Vol. 7, No. 1, 1996.
- [267] J. W. Forrester, "Industrial Dynamics", MIT Press, Massachusetts, 1961.
- [268] J. L. Burbidge, "Five Golden Rules to Avoid Bankruptcy", *Production Engineer*, Vol. 62, No. 10, 1983.
- [269] M. M. Naim, "Simulation and SCM: Methodology before technology", *IEE, Manufacturing Engineer*, Vol. 75, No. 3, 1996, pp122-125.
- [270] M. Johansson, P. Cowling and B. MacCarthy, "Synchronous Supply", *IEE, Manufacturing Engineer*, Vol. 79, No. 1, 200, pp36-40.
- [271] R. Mettrers, "Quantifying the Bullwhip Effect in Supply Chains", *International Journal of Operations Management*, Vol. 15, No. 2, 1997, pp89-100.
- [272] J. Bicheno, M. Holweg and J. Niessmann, "Lean Supply Chain Scheduling", *Proceedings of the 15th International Conference on Production Research*, Vol. 1, 1999, pp601-604.
- [273] SSC (Supply Chain Council), "The Supply Chain Reference Model (SCOR)", SSC, <http://www.supplychain.org>.
- [274] D. Little, R. Rollins and M. Peck, "Modelling Garment Supply Networks", *Proceedings of the 15th International Conference on Production Research*, Vol. 1, 1999, pp553-556.
- [275] J. D. Steadman, "Teaching Takes Off - Flight Simulators For Management Education", *OR/MS Today*, Oct 1992, pp40-44.
- [276] G. Stefansson, T. Kanflo and O. Hultrantz, "Data Sharing: The basis for Integrated Supply Chains", *Proceedings of the 15th International Conference on Production Research*, Vol. 1, 1999, pp611-614.
- [277] Y. Chi and P. M. Wolfe, "XML and DOM in Web Supply Chain Data Interchange", *Proceedings of the 15th International Conference on Production Research*, Vol. 1, 1999, pp607-610.
- [278] D. Kehoe and N. Broughton, "Internet Based Supply Chain Management", *International Journal of Production and Operations Management*, Vol. 21, No. 4, 2001, pp516-524.
- [279] A. J. Williams, "The Development of a Web-based Supplier Capability Proforma to Support Agile Manufacturing", *Proceedings of the 15th International Conference on Production Research*, Vol. 1, 1999, pp641-644.

- [280] L. Enarsson, "Questions about the Supply Chain Management Concept", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp567-570.
- [281] R. Pool, "When Failure is not an Option", MIT Press, Technology Review, Massachusetts July 1998.
- [282] R. Bell, "Manufacturing Paradigms for the Future", Department of Manufacturing Engineering, Loughborough University, 1996.
- [283] W. J. Clinton and A. Gore, "Technology for America's Economic Growth: A new direction to build economic strength", US Government Publication, 1993.
- [284] "Driving Productivity and Growth in the UK Economy", McKinsey Global Institute, 1998.
- [285] G. Kruse, "How Will we Fare in 2020 and Beyond?", IEE, Manufacturing Engineer, Vol. 80, No. 1, 2001, pp38-42.
- [286] M. Porter, "The Competitive Advantage of Nations", 1990, The Macmillian Press, 1990.
- [287] T. J. Hill, "Manufacturing Strategy, The Strategic Management of the Manufacturing Function", MacMillian, 1993.
- [288] D. Rhodes, "Who Needs Strategy?", IEE, Manufacturing Engineer, Vol. 75, No. 6, 1996, pp264-267.
- [289] P. M. Swamidass and W. T. Newell, "Manufacturing Strategy, Environmental Uncertainty and Performance: A path analytical model", Management Science, Vol. 33, No. 4, 1987, pp509-24.
- [290] R. H. Hayes and S. C. Wheelwright, "Restoring Our Competitive Edge", John Wiley, 1984.
- [291] H. Mintzberg and J. A. Waters, "Of Strategies, Deliberate and Emergent", Strategic Management Journal, Vol. 6, 1985, pp257-272.
- [292] A. C. Voss, "Alternative Paradigms for Manufacturing Strategy", International Journal of Operations and Production Management. Vol. 15, No. 4, 1995, pp5-16.
- [293] W. Skinner, "Manufacturing: Missing Link in Corporate Strategy", Harvard Business Review, May-June, 1969.
- [294] W. Skinner, "The Focussed Factory", Harvard Business Review, May-June, 1974.
- [295] T.C. E. Cheng and H. Musaphir, "Theory and Practice of Manufacturing Strategy", International Journal of Production Research, Vol. 34, No. 5, 1996, pp1243-1259.
- [296] L. G. Hrebiniak and W. F. Joyce, "Implementing Strategy", Macmillian, 1984.
- [297] M. T. Sweeney and M. Szwajkowski, "Manufacturing Strategy and Performance: A study of the UK engineering industry", International Journal of Operations and Production Management, Vol. 16, No. 5, 1996, pp25-40.
- [298] R. H. Chenhall, "Strategies of Manufacturing Flexibility, Manufacturing Performance Measures and Organisational Performance: An empirical investigation", Integrated Manufacturing Systems, Vol. 7, No. 5, 1996, pp25-32.
- [299] G. P. White, "A Survey and Taxonomy of Strategy-Related Performance Measures for Manufacturing", International Journal of Operations and Production Management, Vol. 16, No. 3, 1996, pp42-61.

- [300] S. C. Wheelwright, "Manufacturing Strategy: Defining the missing link", *Strategic Management Journal*, Vol. 5, 1984, pp77-91.
- [301] A. T. Joseph, "Formulation of Manufacturing Strategy", *International Journal of Advanced Manufacturing Technology*, Vol. 15, No. 7, 1999, pp522-535.
- [302] J. Mills, K. Platts and M. Gregory, "A Framework for the Design of Manufacturing Strategy Processes: A contingency approach", *International Journal of Operations and Production Management*, Vol. 15, No. 4, 1995, pp17-49.
- [303] J. Mills, A. Neely, K. Platts, H. Richards and M. Gregory, "The Manufacturing Strategy Process: Incorporating a learning perspective", *Integrated Manufacturing Systems*, Vol. 9, No. 3, 1998, pp148-155.
- [304] A. D. Neely and J. F. Mills, "Manufacturing in the UK: Survey of Strategy and Performance Measurement Issues in UK Manufacturing Companies", Working Paper, University of Cambridge, 1993.
- [305] C. E. R. Wainwright and R. Leonard, "A Process Model for Manufacturing Strategy", *Proceedings of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and Achievement*, Loughborough University, Mechanical Engineering Publications, 1997, pp47-52.
- [306] P. J. Sackett, "World Class Manufacturing Linking Future Scenarios, Strategies and Technologies", *Proceedings EUC*, Johannesburg, South Africa, 1996.
- [307] G. Archier and H. Serieyx, "The Type 3 Company2", Gower, Aldershot, 1987, pp32-33.
- [308] C. Rigby, P. Forrester and J. Burnett, "Agile Manufacturing: Is it Appropriate for the UK Ceramics Industry?", *Proceedings of the 15th International Conference on Production Research*, Vol. 2, 1999, pp1535-1538.
- [309] I. McCarthy, "Manufacturing Classification: Lessons from organisational systematics and biological taxonomy", *Integrated Manufacturing Systems*, Vol. 6, No. 6, 1995, pp37-48.
- [310] A. Tharumarajah, A. J. Wells and L. Nemes, "Fundamental Principles of Modern Manufacturing: A critical comparison", *CSIRO Divisional Report No. MTM372*, CSIRO Division of Manufacturing Technology, Australia, 1995.
- [311] J. P. Shewchuk, "Agile Manufacturing: One Size Does Not Fit All", *Proceedings of the International Conference of the Manufacturing Value-Chain*, Kluwer Academic Publishers, 1998, pp143-150.
- [312] G. Stalk and T. M. Houtt, "Competing Against Time", Free Press, 1990.
- [313] R. Booth, "Agile Manufacturing", *IEE, Engineering Management*, Vol. 6, No. 2, 1996, pp105-112.
- [314] R. Nagel, "Understanding Agile Competition: A quick look at how to make your company agile", *Iacocca Institute*, Lehigh University, 1993.
- [315] D. Owen and G. Kruse, "Agile Manufacturing: Follow the customer", *IEE, Manufacturing Engineer*, Vol. 76, No. 2, 1997, pp65-68.

- [316] H. Sharifi, I Barclay and P. J. C. Gough, "Moving Towards Agility: A way for the UK manufacturing to go", Proceedings of the 5th International Conference on Factory 2000, IEE, No 435, 1997, pp15-20.
- [317] Y. Y. Yusuf and M. Sarhadi, "A Framework for Evaluating Manufacturing Enterprise Agility", Proceedings of the 15th International Conference on Production Research, Vol. 2, 1999, pp1555-1558.
- [318] P. T. Kidd, "Agile Manufacturing: Forging new frontiers", Addison-Wesley, 1998.
- [319] A. De Toni and S. Tonchia, "Lean Organisation, Management by Process and Performance Measurement", International Journal of Operations and Production Management, Vol. 16, No. 2, 1996, pp221-236.
- [320] S. Shingo, "A Study of the Toyota Production System from an Industrial Viewpoint", Productivity Press, Cambridge, MA, 1982.
- [321] T. Natio, "Competition and Co-operation: Production Information Systems Which Support the Toyota Production Systems", Proceedings of the 3rd International Symposium on Intelligent Manufacturing Systems, Austria, 1993.
- [322] M. Jones, "A Lean Vision", IEE, Manufacturing Engineer, Vol. 79, No. 6, 2000, pp246-248.
- [323] J. P. Womack and D. T. Jones, "From Lean Production to Lean Enterprise", Harvard Business Review, Vol. 72, No. 1, 1994, pp93-103.
- [324] P. Ahlstrom and C. Karlsson, "Change Processes Towards Lean Production", International Journal of Operations and Production Management, Vol. 16, No. 11, 1996, pp42-56.
- [325] C. Karlsson and P. Ahlstrom, "Assessing Changes Towards Lean Production", International Journal of Operations and Production Management, Vol. 16, No. 2, 1996, pp24-41.
- [326] P. Hines and N. Rich, "The Seven Value Stream Mapping Tools", International Journal of Operations and Production Management, Vol. 17, No.1, 1997, pp46-64.
- [327] E. Nugent and K. Chaharbaghi, "Creativity and Competitiveness", IEE, Manufacturing Engineer, Vol. 74, No. 2, 1995, pp60-62.
- [328] S. Fujii, T. Kaihara, H. Morita and M. Tanaka, "A Distributed Virtual Factory in Agile Manufacturing Environment", Proceedings of the 15th International Conference on Production Research, Vol. 2, 1999, pp1551-1555.
- [329] A. Mowshowitz, "Virtual Organisation", Communications of the ACM", Vol. 40, No. 9, 1997, pp30-37.
- [330] S. L. Goldman, R. N. Nagel and K. Preiss, "Agile Competitors and Virtual Organisation: Strategies for enriching the customer", Van Nostrand Reinhold, 1995.
- [331] NIIP, "Introduction to NIIP Concepts", NIIP Consortium, 1998.
- [332] D. T. Wright and N. D. Burns, "Impact of Globalisation on Organisational Structure and Performance", Proceedings of the Organisational Management Division, International Association of Management, 14th Annual Conference", Canada, 1996, pp58-63.
- [333] J. F. Rayport and J. J. Sviokla, "Exploiting the Virtual Value Chain", Harvard Business Review, Nov-Dec, 1995.

- [334] F. Czerniawska and G. Potter, "Business in a Virtual World", Macmillan Press, 1998.
- [335] W. R. Pape, "Becoming a Virtual Company", IEEE, Engineering Management Review, Vol. 24, No. 2, 1996, pp62-63.
- [336] W. F. Cascio, "Virtual Workplaces: Implications for organisational behaviour", Trends in Organisational Behaviour, John Wiley and Sons Ltd, 1999.
- [337] K. Mattes, "Telecommuting: Balancing business and employee needs", Human Resource Focus, Vol. 63, No. 3, 1992, p3.
- [338] S. E. O'Connell, "The Virtual Workplace Moves at Warp Speed", HR Magazine, March, 1996, pp51-77.
- [339] N. Venkratraman and J. C. Henderson, "Real Strategies for Virtual Organising", Sloan Management Review, Fall, 1998, pp33-47.
- [340] P. E. Clements, T. Papaioannou and J. M. Edwards, "AGLETS: Enabling the virtual enterprise", Proceedings of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and Achievement", Loughborough University, Mechanical Engineering Publications, 1997, pp425-431.
- [341] A. Koestler, "The Ghost in the Machine", Appendix 1, Arkana Books, 1967, pp340-348.
- [342] A. Tharumarajah, A. J. Wells and L. Nemes, "Comparison of the Bionic, Fractal and Holonic Manufacturing System Concepts", International Journal of Computer Integrated Manufacturing, Vol. 9, No. 3, 1996, pp217-226.
- [343] H. Suda, "Future Factory System Formulated in Japan" Japanese Journal of Advanced Automation Technology", Vol. 1, No. 1, 1989, pp15-25.
- [344] H. Suda, "Future Factory System Formulated in Japan" Japanese Journal of Advanced Automation Technology", Vol. 23, No. 3, 1990, pp51-61.
- [345] P. Valckenears and H. Van Brussel, "IMS - Holonic Manufacturing Systems: System Components of Autonomous Modules and Their Control - HMS Principles", IMS Feasibility Study, February, 1994.
- [346] HMS Consortium, "Holonic Manufacturing Systems Concepts", HMS Consortium, <http://hms.ifw.uni-hannover.de/>
- [347] T. Moriwaki and N. Sugimura, "Modelling of Holonic Manufacturing System and its Application to Real Time Scheduling", In T. Moriwaki (ed), Holonic Manufacturing Systems, HMS/WP4 Report, Japan, Dec, 1993.
- [348] R. Bell and S. T. Newman, "IT Tools to Improve the Manufacturing Performance of Metalworking SMEs", Department of Manufacturing Engineering, Loughborough University, EPSRC Project GR/L27077.
- [349] J. Nakane and R. W. Hall, "Holonic Manufacturing: Flexibility the competitive battle in the 1990s", Journal of Production Planning and Control, Vol. 2, No. 1, 1990, pp2-13.
- [350] J. Harrington, "Computer Integrated Manufacturing", New York Industrial Press, 1973.
- [351] S. V. Nagalingam and G. C. I. Lin, "Latest Developments in CIM", Robotics and Computer Integrated Manufacturing, Vol. 15, No. 6, 1999, pp423-430.

- [352] G. C. I. Lin, "The Latest Research Trends in CIM", Keynote Paper, Proceedings of the 4th International Conference on CIM, Singapore, 1997, pp26-33.
- [353] T. M. A. Ari Samadi and K. Hoang, "Shared Computer Integrated Manufacturing for various Types of Production Environment", International Journal of Operations and Production Management, Vol. 15, No. 5, 1995, pp95-108.
- [354] H. B. Marri, A. Gunasekaran and R. J. Grieve, "An Investigation into the Implementation of Computer Integrated Manufacturing in Small and Medium Enterprises", International Journal of Advanced Manufacturing Technology, Vol. 14, 1998, pp935-942.
- [355] R. E. McGaughey and D. W. Roach, "CIM Planning: An exploratory study of factors practitioners perceive important to CIM planning success", International Journal of Computer Integrated Manufacturing, Vol. 14, No. 4, 2001, pp353-366.
- [356] P. J. Sackett and A. J. Heslop, "Modelling Strategies for Appraisal of CIM Sytems", in Advances in CIM (ed P. J. Sackett), JAI Press Limited, London, Vol. 1, 1990, pp49-73.
- [357] G. Sohlenius, "Concurrent Engineering", Keynote Paper, Proceedings of the CIRP Manufacturing Systems, Vol. 41, No.2, 1992, pp645-655.
- [358] R. I. Winner, J. P. Pennell, H. E. Bertrand and M. M. G. Slusarczyk, "The Role of Concurrent Engineering in Weapon System Acquisition", IDA Report R-338.
- [359] A. G. Molina, A. H. Al-Ashaab, T.I.A. Ellis, R.I.M. Young and R. Bell, "A Review of Computer Aided Simultaneous Engineering Systems", Research in Engineering Design Journal, Vol. 7, 1995, pp38-63.
- [360] I. Stevenson, "IT Based Tools for Concurrent Engineering", Proceedings of the 8th CIM-Europe Annual Conference", Birmingham, 1992, pp157-166.
- [361] E. J. Haug, "Concurrent Engineering of Mechanical Systems", ASME, 1994.
- [362] D. D. Bedworth, M. R. Henderson and P. M. Wolfe, "Computer Integrated Design and Manufacturing", McGraw-Hill, 1991.
- [363] C. McMahon and J. Browne, "CAD/CAM: From principles to practice", Addison-Wesley, 1993.
- [364] R. J. Clayton, "Integration of CAD and CAM: Fact, Fiction or Dream", Proceedings of the SME/CASA Autofact III Conference, 1981.
- [365] T.I.A. Ellis, A. Molina, R.I.M. Young and R. Bell, "An Information Sharing Platform for Concurrent Engineering", in Integrated Manufacturing Systems Engineering, Chapman Hall, 1995, pp262-276.
- [366] D. Shetty and K. Kolluri, "Concurrent Product and Process Development in the Aerospace Industry", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp239-242.
- [367] G. Schneider, S. Bauman and J. Schweitzer, "Integrating and Co-ordinating Major Software Systems with Workflow Management Systems", Proceedings of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and

- Achievement", Loughborough University, Mechanical Engineering Publications, 1997, pp549-554.
- [368] G. Chryssolouris, "Manufacturing Systems: Theory and practice", Springer-Verlag, 1991.
- [369] G. Chryssolouris, "Flexibility and Its Measurement", Annals of the CIRP, Vol. 45, No. 2, 1996, p581-587.
- [370] D. Little and P. C. Jarvis, "Survey of Current UK Shop Floor Scheduling Practices", Control, BPICS, Dec 1992/Jan 1993, pp24-28.
- [371] R. N. Conway, W. L. Maxwell and L. Miller, "Theory of Scheduling", Addison Wesley, 1967.
- [372] K. R. Baker, "Introduction to Scheduling and Sequencing", John Wiley and Sons, 1974.
- [373] T. E. Morton and D. W. Pentico, "Heuristic Scheduling Systems", John Wiley and Sons, 1993.
- [374] P. Jarvis, G. K. Kenworthy, D. Little and J. K. Porter, "Best Practice Benchmarks for Planning and Scheduling", Proceedings of the 4th International Conference on Factory 2000, IEE, No 398, 1994, pp306-311.
- [375] K. N. McKay and V. C. S. Wiers, "Unifying the Theory and Practice of Production Scheduling", Journal of Manufacturing Systems, Vol. 18, No. 4, 1999, pp241-255.
- [376] C. Ortiz, "Implementation Issues: A recipe for scheduling success", IEE Solutions, March, 1996, pp29-32.
- [377] R. J. Burrows and M. N. Polkinghome, "Appraisal of New Technological Solutions Applied to Scheduling Systems for SMEs", Proceedings of the 5th International Conference on Factory 2000, IEE, No 435, 1997, pp229-234.
- [378] J. W. Bertrand, J. C. Wortmann and J. Wijngaard, "A Structured and Design Oriented Approach", Elsevier Science, 19990.
- [379] Baan, "Triton Manufacturing Control Software: The future has no boundaries", Baan International B.V., 1994.
- [380] S. M. Lee and M. J. Schniedermans, "Operations Management", Houghton Mifflin Company, 1994.
- [381] M. Luscombe, "MRPII Integrating the Business: A Practical Guide for Managers", Butterworth-Heinemann Limited, 1993.
- [382] J. J. Smith, "TOC and MRPII: From Theory to Results", Bradley University, Peoria, Illinois, 1994.
- [383] D. Little, K. Porter, P. C. Jarvis and J. G. Kenworthy, "MRPII and Stand Alone Schedulers: The relationships", Integrated Manufacturing Systems, Vol. 6, No. 1, 1995, pp22-26.
- [384] R. F. Jacobs, "OPT Uncovered: Many Production Planning and Scheduling Concepts can be Applied With or Without Software", Industrial Engineering, 1987.
- [385] E. M. Goldratt and J. Cox, "The Goal", North River Press Inc, 1984.
- [386] E. M. Goldratt and R. E. Fox, "The Race", North River Press Inc, 1986.
- [387] E. M. Goldratt, "The Theory of Constraints", North River Press Inc, 1990.

- [388] T. Hutchin, "The Challenge of The Theory of Constraints to Accepted Practice in Production Control", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp419-422.
- [389] T. Ohno, "Toyota Production System: Beyond Large Scale Production", Productivity Press, 1988.
- [390] J. Browne, J. Harhen and J. Shivnan, "Production Management Systems: A CIM Perspective", Addison-Wesley, 1988.
- [391] A. S. Sohal and D. Naylor, "Implementation of JIT in a Small Manufacturing Firm", Production and Inventory Management Journal, BPICS, Vol. 33, No. 1, 1992, pp20-25.
- [392] D. Samson, "Manufacturing and Operations Strategy", Prentice-Hall, 1991.
- [393] T. E. Vollman, W. L. Berry and D.C. Whybark, "Manufacturing Planning and Control Systems", Irwin, 1988.
- [394] G. Plenert, "MRP, JIT and OPT: A study", in Modern Production Management System, Elsevier Science, 1987, pp729-734.
- [395] K. I. Lee and J. H. Park, "A Collaborative Scheduling System for Make-To-Order Manufacturing", Annals of the CIRP, Vol. 45, No. 1, 1996, pp461-464.
- [396] D. Little, R. Rollins, M. Peck and K. J. Porter, "Integrated Planning and Scheduling in the Engineer-To-Order Sector", International Journal of Computer Integrated Manufacturing", Vol. 13, No. 6, 2000, pp545-554.
- [397] S. Davis, "Future Perfect", Addison-Wesley, 1987.
- [398] J. B. Pine, "Mass Customisation: The New Frontier in Business Competition", Harvard Business School Press, 1996.
- [399] J. B. Pine, D. Peppers and M. Rogers, "Do You Want to Keep Your Customers Forever?", Harvard Business Review, Mar/Apr, 1995, 103-114.
- [400] S. Suresh, "Mass Customisation: A strategy for knowledge creation and organisational learning", International Journal of Technology Management, 1996, pp846-858.
- [401] P. Hanson, "Total Differentiation", IEE, Manufacturing Engineer, Vol. 76, No. 3, 1997, pp133-135.
- [402] D. K. Rigby, "Management Tools and Techniques", Bain and Company, 1997.
- [403] R. T. Beaty, "Mass Customisation", IEE, Manufacturing Engineer, Vol. 75, No. 5, 1996, pp217-220.
- [404] S. Fox, "Managing Product Personalisation", Engineering Management Journal, Vol. 11, No. 4, 2001, pp174-180.
- [405] P. Ahlstrom and R. Westbrook, "Implications of Mass Customisation for Operations Management: An exploratory survey", International Journal of Operations and Production Management, Vol. 19, No. 3, 1999, pp262-274.
- [406] C. Popper, "Holistic Framework for IT Governance", Centre for Information Policy Research, Harvard University, 2000.

- [407] P. Benton, "Information for Strategic Advantage", in *Information Management in Competitive Success*, Pergamon Infotech Limited, 1996, pp 3-10.
- [408] J. Papows, "Enterprise.com: Market Leadership in the Information Age", Nicholas Brealey Publishing, 1998.
- [409] Interforum, "Commercial Opportunities and Threats in the Networked Economy", Interforum UK Ltd, Richmond, Surrey, 1997.
- [410] N. Colin, "Information Management in Crisis", *Computer Audit Update*, Feb, 1995, pp6-12.
- [411] B. Johnson, J. Stewart and R. Van't Veen, "In Times of Radical Change", CCTA, London Stationary Office, 1997.
- [412] J. Browing, N. Macdonald, R. Mack, D. Philips, J. Pultz, R. Terdiman, G. Weiss and C. Ross, "Are IT Strategies in Midsize Enterprises E-Ready?", Gartner Group, 2000.
- [413] M. E. Porter and V. E. Miller, "How Information Gives You Competitive Advantage", *Harvard Business Review*, Vol. 63, 1985, pp149-160.
- [414] D. M. Schroder, "New Technology and the Small Manufacturer: Panacea or Plague?", *Journal of Small Business Management*, Vol. 27, No. 3, 1989, pp1-10.
- [415] E. Lefebvre and L. A. Lefebvre, "Information and Telecommunications Technologies: The impact of their adoption on small and medium-sized enterprises", IRDC, 1996.
- [416] R. Laracuenta et al, "IT Strategies for Midsize Enterprises: 2000 and Beyond", *Strategic Analysis Report*, Gartner Group, 1998.
- [417] D. S. J. Remenyi, "Increase Profits with Strategic Information Systems", National Computing Centre Limited, NCC Publications, Manchester, 1988.
- [418] J. C. Henderson and N. Venkatraman, "Strategic Alignment: A process model for organisational transformation through IT", *Transforming Organisations*, Oxford University Press, 1992.
- [419] A. L. Lederer and V. Sethi, "The Implementation of Strategic Information Systems Planning Methodologies", *MIS Quarterly*, Vol. 12, 1988, pp441-461.
- [420] J. N. Luffman, P. R. Lewis and S. H. Oldach, "Transforming the Enterprise: The alignment of business and IT strategies", *IBM systems Journal*, Vol. 32, No. 1, 1993, pp189-221.
- [421] R. D. Galliers and A. R. Sutherland, "Information Systems Management and Strategy Formulation: The stages of growth model revisited", *Journal of Information Science*, Vol. 1, No. 1, 1991, pp89-114.
- [422] J. Barkan, B. Bond, A. Hilwa, R. Laracueenta, N. MacDonald, D. Tunik and B. Lett, "ITM Scenario: A Strategic Road Map for Midsize Enterprises", Gartner Group, 1997.
- [423] J. M. Burn, "Information Systems Strategies and the Management of Organisational Change - A Strategic Alignment Model", *Journal of Information Technology*, Vol. 8, pp127-136.
- [424] V. Sambamurthy, S. Venkataraman and G. Desanctis, "The Design of IT Planning Systems for Varying Organisational Contexts", *European Journal of Information Systems*, Vol. 2, 1993, pp23-35.
- [425] M. Scott-Morton, "The Corporation of the 1990's", Oxford University Press, 1990.

- [426] M. J. Earl and D.F. Feeny, "Is Your CIO Adding Value?", Sloan Management Review, Vol. 35, No. 3, 1994, pp11-20.
- [427] L. Wilcocks, D. F. Feeny and G. Islei, "Managing IT as a Strategic Resource", McGraw-Hill, 1997.
- [428] P. Larsen, R. Tonge and M. Roberts, "Exploring IS Planning in High-Growth Medium-Sized Enterprises", Journal of General Management, Vol. 26, No. 3, 2001, pp76-89.
- [429] M. Sharge, "The Real Problem with Computers", Harvard Business Review, Sept-Oct, 1997, pp178-188.
- [430] T. H. Davenport, "Information Ecology: Mastering the Information and Knowledge environment", Oxford University Press, 1997.
- [431] P. A. Strassmann, "The Squandered Computer: Evaluating the Business Alignment of Information Technologies", The Information Economics Press, 1997.
- [432] M. Bensaou and M. J. Earl, "The Right Mind-set for Managing Information Technology", Harvard Business Review, Sept-Oct, 1998, pp118-128.
- [433] J. Hale, "CIO: Director or Manager", Contra, Butler Group Ltd, June, 2001.
- [434] Sun Microsystems, "Internet Essentials", Sun Microsystems Limited, Bagshot, Surrey, 1998.
- [435] T. M. Siebel and P. House, "Cyber Rules: Strategies for Excelling at E-Business", Doubleday Publishing, 1999.
- [436] P. Makey (ed), "The Corporate Intranet/Internet: Strategies and Technologies", Butler Publishing Limited, 1997.
- [437] A. J. Kennedy, "The Internet and World Wide Web", Penguin Group, 1995.
- [438] K. Downes, M. Ford, H. KimLew, S. Spanier and T. Stevenson, "Internetworking: Technologies Handbook", Macmillian, 1998.
- [439] J. Jina and D. T. Wright, "Using Internet Technology for Competitive Advantage", Proceedings of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and Achievement", Loughborough University, Mechanical Engineering Publications, 1997, pp445-452.
- [440] Cyber Atlas, "The World's Online Population", <http://www.cyberatlas.com>.
- [441] J. Taylor, "Engineering in the Information Age", IEE, Engineering Management Journal, Vol. 8, No. 6, 1998, pp227-287.
- [442] Net Names, "World Domain Statistics", <http://www.domainstats.com>.
- [443] J. Sullivan, "What are the Functions of Corporate Home Pages", Journal of World Business, Vol. 34, No.2, 1999, pp193-210.
- [444] D. Schutzer, "Electronic Commerce", US National Information Infra-structure White Paper, 1999.
- [445] Booz-Allen and Hamilton, "Scoping of Issues", G7 Global Market Place for SMEs First Annual Conference, Bonn, 1997, <http://www.ispo.ccc.be>.
- [446] KPMG, "Electronic Commerce: A survey of small and medium sized enterprises", KPMG Consulting, 1999.

- [447] P. Sweet, "Doing the E-business: Market Overview and Analysis", Conspectus, December, 2000, pp2-4.
- [448] KPMG, "Electronic Commerce Research Report", KPMG Consulting, 1997.
- [449] R. Burnett, "Legal Aspects of E-Commerce", IEE, Manufacturing Engineer, Vol. 79, No. 3, 2000, pp115-118.
- [450] B. Radtke and S. Cournoyer, "E-Commerce Models in Manufacturing", Gartner Group, 2000.
- [451] C. Campbell and G. Cruz, "Profiles of E-Business Opportunities in Manufacturing", Gartner Group, 2000.
- [452] B. Mathieu, "Global Consumer E-Commerce Forecast Update", Gartner Group, 1999.
- [453] H. Min and W. P. Galle, "Electronic Commerce Usage in Business-to-Business Purchasing", International Journal of Operations and Production Management, Vol. 19, No. 9, 1999, pp909-921.
- [454] R. L. Keeney, "The Value of Internet Commerce to the Customer", Management Science, Vol. 45, No. 4, 1999, pp533-542.
- [455] J. F. Rayport and J. J. Sviokla, "Managing in the Marketspace", Harvard Business Review, Nov-Dec, 1994, pp141-150.
- [456] S. Ghosh, "Making Business Sense of the Internet", Harvard Business Review, Mar-Apr, 1998, pp126-135.
- [457] J. Browning, M. Yamamoto-Krammer and K. Potter, "SME Alert: E-Business says, Show Me The Money", Gartner Group, 2000.
- [458] A. Tesler, "The Computer in the 21st Century", Scientific America, Special Issue, 1995, pp 1-11.
- [459] M. Brandel, "Think Global Act Local", Global Innovators Series, Computing, April, 1997, pp8-9.
- [460] P. J. Ranky, "Computer Networks for World Class CIM Systems", CIMware Ltd, 1990.
- [461] W. M. Malone and J. F. Rockart, "Computers, Networks and the Corporation", Computers in the 21st Century, Scientific America, Special Issue, 1995, pp 140-147.
- [462] A. Toffler, "Future Shock", Bantam Doubleday Dell Publishing Group, 1985.
- [463] B. Jain and A. Agrawala, "Open Systems Interconnection", McGraw-Hill, 1993.
- [464] A. B. Tucker Jnr, "The Computer Science and Engineering Handbook", CRC Press, 1996.
- [465] C. F. Gutierrez and D. Holt, "Asynchronous Transfer Mode: An engineering management perspective", IEE, Engineering Management Journal, Vol. 8, No. 1, 1998, pp177-185.
- [466] E. De Bony, "Global Networks and Interoperability", I&T Magazine, Winter, No. 16, 1995, pp11-13.
- [467] F. Soliman and M. Youssef, "The Impact of Some Recent Developments in E-business on the Management of Next Generation Manufacturing", International Journal of Operations and Production Management, Vol. 21, No.5/6, 2001, pp538-564.

- [468] R. H. Weston, "Manufacturing Business Systems: Requirements and Current Practice", Manufacturing Business Systems Module - Course Notes, Loughborough University, 2000.
- [469] R. Weston, "Model-Driven, Component-Based Approach to Reconfiguring Manufacturing Software Systems", International Journal of Operations and Production Management, Vol. 19, No. 8, 1999, pp834-855.
- [470] R. Prins, "Developing Business Objects: A framework driven approach", McGraw-Hill, 1996.
- [471] R. H. Weston, "Next Generation Manufacturing Business Systems and the Role of Component-based Systems Engineering", Manufacturing Business Systems Module - Course Notes, Loughborough University, 2000.
- [472] D. J. Tudor and I. J. Tudor, "Systems Analysis and Design - A Comparison of Structured Methods", MacMillan, 1997.
- [473] S. H. Hum and H. H. Sim, "Time-based Competition: Literature review and implications for modelling", International Journal of Operations and Production Management, Vol. 16, No. 1, 1994, pp75-90.
- [474] Deloitte and Touche, "ERP's Second Wave: Maximising the value or ERP-enables processes", Deloitte and Touche Consulting, 1998.
- [475] J. Orlicky, "Material Requirements Planning: The new way of life in production and inventory management", McGraw-Hill, 1975.
- [476] D. W. Fogarty and T. R. Hoffman, "Production and Inventory Management", South-Western Publishing Company, 1983.
- [477] D. W. Mcleavay and S. L. Narasimhan, "Production Planning and Inventory Control", Allyn and Bacon, 1985.
- [478] G. W. Plossl, "Production and Inventory Control: Principles and Techniques", Prentice-Hall, 1985.
- [479] O. W. Wight, "Manufacturing Resource Planning: MRPII: Unlocking America's Productivity Potential", John Wiley and Sons, 1995.
- [480] J. N. Petroff, "handbook of MRPII / JIT Integration and Implementation", Prentice-Hall, 1993.
- [481] P. Knutton, "Partners Make the Difference", Engineering Computers, Vol. 7, No. 19, 1994, pp 18-19.
- [482] E. Keller, "Enterprise Resource Planning (ERP): Quantifying the vision", Gartner Group, 1993.
- [483] J. Bautista, M. Mateo, J. Pereira and R. Companys, "From EOQ to the e-ERP: Impact on the organisation", 15th IFAC World Congress on Automatic Control, Barcelona, Spain, July 21-26, 2002.
- [484] R. Jones and G. Kruse, "Making a Meal of ERP", IEE, Manufacturing Engineer, Vol. 18, No. 2, 1999, pp61-64.
- [485] AMR Research, "Enterprise Resource Planning Software Report 1998-2003" AMR Research, Boston, MA, 1999.

- [486] TechRepublic, "The Six Largest ERP Vendors", Technology Republic, 2000, www.techrepublic.com.
- [487] W. Chamberlain and G. Thomas, "The Future of MRPII: Headed for the Scrap Heap or Rising from the Ashes? and MRPII Buyers Guide", IIE Solutions, Vol. 27, No. 7, 1995, pp32-39.
- [488] J. Shonfield, "Enterprise Software: Best of the Rest", Conspectus, February, 1999, pp14-15.
- [489] S. Baker, "SAP's Expanding Universe", Business Week, 14th September, 1998, pp168-170.
- [490] J. Wolfenden, "Global Manufacturing", IEE, Manufacturing Engineer, Vol. 73, No.2, 1994, pp79-81.
- [491] G. Stewart, "Dimensions of Exploiting Enterprise Systems: A hermeneutic approach", 15th IFAC World Congress on Automatic Control, Barcelona, Spain, July 21-26, 2002.
- [492] E. Nelson and E. Ramstad, "Trick or Treat: Hershey's biggest dud has turned out to be its new technology", The Wall Street Journal, 29th October, 1999.
- [493] F. Aglen, "Manufacturing Systems: Careful consumption", Conspectus, August, 1999, pp2-4.
- [494] S. Durumusoglu, H. Sumen and V. Z. Yenen, "The State-of the-art of MRP/MRPII Implementation in Turkey", Production Planning and Control, Vol. 7, No. 1, 1996, pp2-10.
- [495] A. Teltumbde, "A Framework for Evaluating ERP Projects", Proceedings of the 15th International Conference on Production Research, Vol. 1, 1999, pp725-728.
- [496] D. N. Halsall, A. P. Muhlemaan, D. H. R. Price, "Production Planning and Scheduling Frameworks for Smaller Manufacturing Enterprises", Proceedings of the International Conference on Systems, Man and Cybernetics, Part 4, Le Touquet, France, 17-20 Oct, 1993, pp33-38.
- [497] J. West and C. Ptak, "Now Hear This: ERP for Small Business", APICS, 1996, www.apics.org/sigs/articles/nowhear.htm.
- [498] D. Little, C. J. Gavin, D. J. Guenaoui and C. Keller-Jackson, "Supporting SME Information Development Using a Structured Method and Tool for Package Selection", Proceedings of the International Conference of the Manufacturing Value-Chain, Kluwer Academic Publishers, 1998, pp497-504.
- [499] D. Little, "Development of a Package Selection Method and Tool for SMEs", Computer Integrated Manufacturing Systems, Vol. 11, No. 4, 1998, pp351-355.
- [500] J. Darlington and C. Moar, "MRP Rest in Peace", Management Accounting, October, 1996, pp14-20.
- [501] M. Mason, "Wither MRP?", IEE, Manufacturing Engineer, Vol. 76, No. 5, 1997, pp212-214.
- [502] G. Q. Huang and K. L. Mak, "Web-integrated Manufacturing: Developments and Emerging Issues", International Journal of Computer Integrated Manufacturing, Vol. 14, No. 1, 2001, pp3-13.
- [503] A. Hochberg, "Enterprise Applications, The Internet and E-Commerce: Software Package Plans Across Europe", Gartner Group, 2000.

- [504] K. Steenstrup, "Oracle Takes Another Step Towards a Complete ERP/II Solution", Gartner Group, 2002.
- [505] D. Prior and B. Burton, "ERP/II SAP/Oracle Escalation Wake-up Call", Gartner Group, 2002.
- [506] K. Brant, "Discrete Manufacturing: The promise of the ERP/II model", Gartner Group, 2002.
- [507] Y. Genovese, B. Bond, B. Zrimsek, N. Frey, "The Transition to ERP/II: Meeting the challenges", Gartner Group, 2001.
- [508] M. Coleman, "Has ERP Expired?", Computer Business Review, December, 1999, pp12-16.
- [509] J. F. Rockart and M. E. Treacy, "The CEO Goes On-line" Harvard Business Review, Jan-Feb, 1982, 81-93.
- [510] H. L. Watson, G. Houdeshel and R. K. Rainer Jnr, "Building Executive Information Systems and other Decision Support Applications", John Wiley and Sons, 1997.
- [511] L. W. Belcher and H. J. Watson, "Assessing the Value of Conoco's EIS", MIS Quarterly, Vol. 17, No. 3, 1993, pp239-253.
- [512] J. H. Nord and G. D. Nord, "Executive Information Systems: A study and comparative analysis", Information and Management Journal, Vol. 29, 1995, pp95-106.
- [513] D. Andrew and P. Makey (eds), "Business Intelligence: Information synergy for the enterprise", Butler Group, Vol. 4, 1997.
- [514] P. Paliva, A. Kumar, N. Kumar and R. Hendon, "Information Requirements of a Global EIS: An exploratory macro assessment", Decision Support Systems, Vol. 16, 1999, pp169-179.
- [515] M. Jarke, M. Lenezerini, Y. Vassiliou and P. Vassiliadis, "Fundamentals of Data Warehouses", Springer-Verlag, 2000.
- [516] W. H. Inmon, "Building the Data Warehouse: 2nd Edition", John Wiley and Sons, 1996.
- [517] C. Adamson and M. Venerable, "Data Warehouse Design Solutions", John Wiley and Sons, 1998.
- [518] R. Kimball, L. Reeves, M. Moss and W. Thornthwaite, "The Data Warehouse Life Cycle Toolkit: Export methods for designing, developing and deploying data warehouses", John Wiley and Sons, 1998.
- [519] R. Kimball, "The Data Warehouse Toolkit", John Wiley and Sons, 1996.
- [520] J. Weldon, "Warehouse Cornerstones", Byte, January, 1997, pp85-88.
- [521] C. Imhoff, R. Sousa, W. H. Inmon and C. Amhoff, "Corporate Information Factory", John Wiley and Sons, 1997.
- [522] A. R. Simon, "90 Days to the Data Mart", John Wiley and Sons, 1998.
- [523] D. S. Linthicum, "Enterprise Application Integration", Addison-Wesley, 2000.
- [524] S. V. Walton and J. N. D. Gupta, "Electronic Data Interchange for Process Change in an Integrated Supply Chain", International Journal of Operations and Production Management, Vol. 19, No. 1, 1999, pp372-388.
- [525] D. M. Ferguson, "Ten Major Challenges an EC Manager Must Conquer to be World Class in the 21st Century", The Journal of Electronic Commerce, Vol. 11, No. 3, 1998, pp1-3.

- [526] M. S. Threlkel and B. C. Kavan, "From Traditional EDI to Internet-based EDI: Managerial considerations", *Journal of Information Technology*, Vol. 14, No. 4, 1999, pp347-360.
- [527] M. Hendry, "Implementing EDI", Srtech House, 1993.
- [528] E. DeBony, "Global Network and Interoperability", *I&T Magazine*, No. 16, 1994, pp11-13.
- [529] M. Grifkins, "EDI Technology", Blenheim Online, 1989.
- [530] D. Gulbransen, "The Complete Idiots Guide to XML", Que Publishing, 2000.
- [531] M. Hills, "Intranet Business Strategies", John Wiley and Sons, 1997.
- [532] A. Donghi, A. Ravarini and M. Tagliavini, "The Adoption of Intranet within SMEs: A Case Study", *Proceedings of the 10th International IFIP WG 5.2/5.3 Conference - Prolamat 98*, 1998, Paper #8.
- [533] G. Buonanno, A. Ravarini, D. Sciuto and M. Tagaliavini, "How Internet Connected SMEs Exploit the Potential of the Net", *Proceedings of the International Information Resources Management Association Conference*, Boston MA, 1998.
- [534] Sun, "Intranet Essentials", Sun Microsystems Computers Limited Publications, 1997.
- [535] A. Fitzgerald, "It's Good to Browse", *IEE Manufacturing Engineer*, Vol. 77, No. 4, 1998, pp172-173.
- [536] S. McGovern, "The Intranet: Generating New Revenues, Increasing Customer Satisfaction, Reducing Costs", Netscape Communications Corporation, 1997.
- [537] B. Collins, "Designing Secure Intranets", *IEE, Manufacturing Engineer*, Vol. 77, No. 6, 1998, pp264-268.
- [538] KPMG, "Replacing Inventory with Information: Advanced Planning Systems", KPMG Consulting, 2000.
- [539] APS Insight, "Will APS replace MRP?", *APS Insight*, Issue 5, www.apsinsight.com
- [540] i2 Technologies, "Intelligent eBusiness: Customer-centric eBusiness for sustainable growth and profitability", July, 1999, i2 Technologies Inc.
- [541] Preactor, "Advanced Planning Systems", Preactor International, 1999.
- [542] APS Insight, "APS and B2B", *APS Insight*, Issue 3, www.apsinsight.com
- [543] T. Lewins, "Fit for Purpose", *IEE, Manufacturing Engineer*, Vol. 79, No. 6, 2000, pp236-239.
- [544] IDAT, "Increased Accuracy with ADC", IDAT Consulting, 1996, www.idat.com/baccu.htm
- [545] K. Watson, "Finite scheduling: Who needs it?", *The Engineer*, 7th March, 1996, p17.
- [546] W. Close, "Applications That Enable Customer Relationship Management", Gartner Group, 21st July, 1999.
- [547] W. Close et al, "Functionality Comparison: Business-to-Business Large Enterprise CRM Suites", Gartner Group, 6th November, 2001.
- [548] M. Butler, "Value and IT", Butler Group, Contra, June, 2001.
- [549] Siebel, "Driving Performance for Small and Medium Businesses with Customer Relationship Management", Siebel Systems Inc, February, 2002.
- [550] Butler Group, "Legacy Renovation", Butler Direct Limited, November, 1999.

- [551] J. Edwards, T. Millea, S. McLeod and I. Coutts, "Agile System Design and Build", MSI Research Institute, Loughborough University, 1998.
- [552] D. Andrew (ed), "Component Based Development", Butler Consulting Group Limited, 1998.
- [553] M. I. Barber and R. H. Weston, "Scoping Study on Business Process Reengineering: Towards successful IT applications", International Journal of Production Research, Vol. 36, No. 3, 1998, pp575-601.
- [554] A. Bertiss, "Software Methods for Business Process Reengineering", Springer-Verlag, 1996.
- [555] R. Wieringa, "A Survey of Structured and Object-Oriented Software Specification Methods and Techniques", ACM Computing, Vol. 30, No. 4, 1998, pp459-527.
- [556] J. Sodhi and P. Sodhi, "Software Reuse: Domain analysis and design process", McGraw-Hill, 1999.
- [557] P. E. Clements, "Requirements for Software Systems Which Enable the Flexible Enterprise", Proceedings of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics and Achievement", Loughborough University, Mechanical Engineering Publications, 1997, pp433-438.
- [558] R. H. Weston, "Model-Driven Component-Based Approach to Reconfiguring Manufacturing Software Systems", International Journal of operations and Production Management", Vol. 19, No. 8, 1999, pp834-835.
- [559] C. J. Petrie, "Agent-Based Engineering, The Web and Intelligence", Stanford Centre for Design Research, Working Draft to Appear in IEEE Expert.
- [560] C. Szyperski, "Component Software: Beyond Object-Oriented Programming", Addison-Wesley, 1997.
- [561] C. Hewitt, "Viewing Control Structures As Patterns of Passing Messages", Artificial Intelligence, Vol. 8, No. 3, 1977, pp323-364.
- [562] H. S. Nwana, "Software Agents: An overview", The Knowledge Engineering Review, Vol. 11, No. 3, 1996, pp205-244.
- [563] L. Ming, Y. Xiaohong, M. M. Tseng and Y. Shuzi, "A CORBA-based Agent-Driven Design for Distributed Intelligent Manufacturing Systems", Journal of Intelligent Manufacturing Systems, Vol. 9, 1998, pp457-465.
- [564] N. R. Jennings, P. Faratin, M. J. Johnson, T. J. Norman, P. O'Brien and M. E. Wiegand, "Agent-based Business Process Management", Department of Electronic Engineering, Queen Mary and Westfield College, London, 1995.
- [565] J. Mann, "Workflow and Enterprise Application Integration", 2002, <http://www.messageq.com>.
- [566] Gartner Group, "Application Integration: Better Ways to Make Systems Work Together", Gartner Group Conference Proceedings, Stanford, 1998.
- [567] E. L. Appleton, "How to Survive ERP", Datamation, Vol. 43, No. 3, 1997, pp50-58.
- [568] A. Halborg. "Managing Growth within Small Motor Industry Suppliers", Proceeding of the 1st International Conference on Managing Enterprises - Stakeholders, Engineering, Logistics

- and Achievement", Loughborough University, Mechanical Engineering Publications, 1997, pp177-182.
- [569] A. Walker, C. Lee and A. Lung, "Improvement of Management Efficiency in a Small High Tech Company", Proceedings of the 5th International Conference on Factory 2000, IEE, No 435, 1997, pp76-81.
- [570] D. Wastell and A. Stewards, "An Information System Profile of the UK Manufacturing Sector", Journal of Information Technology", Vol. 10, No. 3, 1995, pp179-189.
- [571] R. Cagliano, G. Spina, G. Verganti, and G. Zotteri, "Designing BPR Support Services for Small Firms", Int. Journal of Operations and Production Management", Vol. 18, No.9/10, 1999, pp865-885.
- [572] R.H. Weston, J. M. Edwards and A. Hodgson, "Enabling Methods, Tools and Utilities for Enterprise Integration", Core Project, Final Project Report to EPSRC, Swindon, UK, 1998.
- [573] B. Allison, T. Sullivan, A. Owen, J. Rice, A. Rothwell and C. Saunders, "Research Skills for Students", Kogan Page, 1998.
- [574] L. Bickman and D. J. Rog, "Handbook of Applied Social Research Methods", Sage Publications, 1998.
- [577] R. K. Yin, "Case Study Research", Design and Methods 2nd Edition, Sage Publications Limited, 1994.
- [576] C. Robson, "Real World Research", Blackwell Publishing Limited, 1993.
- [577] M. S. Lewis-Beck, "Research Practice", Sage Publications, 1994.
- [578] R. M. Grooves, "Survey Errors and Survey Costs", John Wiley, 1989.
- [579] M. B. Miles and A. M. Huberman, "Qualitative Data Analysis: An expanded source book", Sage Publications, 1994.
- [580] M. Stouthamer-Loeber and W. B. Van Kammen, "Data Collection and Management: A practical guide", Sage Publications, 1995.
- [581] G. Hoinville, R. Jowell and Associates, "Survey Research Practice", Gower, 1985.
- [582] CCTA, "SSADM Version 4", NCC Publications, Blackwell, 1990.
- [583] K. Robinson and G. Berrisford, "Object-Oriented SSADM", Prentice-Hall, 1994.
- [584] R.H. Weston, J. M. Edwards and A. Hodgson, "Enabling Methods, Tools and Utilities for Enterprise Integration", Core Project, Final Project Report to EPSRC, Swindon, UK, 1998.
- [585] C. Hicks and P. A. Braiden, "Computer-Aided Production Issues in the Engineer-to-order Production of Complex Capital Goods Using a Simulation Approach", International Journal of Production Research, Vol. 38, No. 18, 2000, pp4783-4810.
- [586] R. Storey, "Introduction to Cost and Management Accounting", Macmillan, 1995.
- [587] G. Thomas, "Product Configuration for "To-Order Industries", IIE Solutions, March, 1996, pp34-38.
- [588] A. Federgruen and Z. Katalan, "The Impact of Adding a Make-to-order Item to a Make-to-stock Production System", Journal of Management Science, Vol. 45, No. 7, 1999, pp980-994.

- [589] J. W. Bertrand and D. R. Muntslag, "Production Control in Engineer-to-order firms", International Journal of Production Economics, Vol. 30, 1993, pp3-22.
- [590] R. H. Weston, E. De La Hostria, K. Kosanke and E. R. Noxon, "Business Benefits From Enterprise Integration", Workshop 5, Working Group 1, Proceedings of the ICEIMT'97 International Conference on Enterprise Integration and Modelling Technology, Vol. 1, 1997, pp152-162.
- [591] M. J. Kelly, "Business Measurement Process: Industrial products", KPMG Consulting, 1997.
- [592] R. J. Thompson and L. Redstone, "Business Process Management: Maintaining control in an environment of rapid change", Proceedings of the 5th International Conference on Factory 2000, IEE, No 435, 1997, pp94-98.
- [593] C. Baudoin and G. Hollowell, "Realising the Object-Orientated Lifecycle", Prentice-Hall, 1996.
- [594] J. Stankovic, "Misconceptions About Real-time Computing: A real problem for next-generation computing", IEEE Computing, Vol. 21, No. 10, 1998, pp45-62.
- [595] T. Manns and M. Coleman, "Software Quality Assurance", Macmillian, 1996.
- [596] M. J. Earl and B. Kuan, "How New is Business Process Redesign?", European Management Journal, Vol. 12, No. 1, 1994, pp20-30.
- [597] T. R. Furey and S. G. Diorio, "Making Reengineering Strategic", Planning Review, Vol. 20, No.2, 1994, pp7-11.
- [598] E. Ramcharmdas, "Xerox Creates a Continuous Learning Environment for Business Transformation", Planning Review, Vol. 20, No.2, 1994, pp34-38.
- [599] V. Grover, J. T. C. Teng and K. D. Fiedler, "IT Enabled Business Process Redesign: An Integrated Planning Framework", OMEGA International Journal of management Science, Vol. 21, No. 4, 1993, pp433-447.
- [600] V. Stich and A. Kees, "The Latest Modelling and Implementation Techniques for an Extended Production Management System", Proceedings of the International Conference of the Manufacturing Value-Chain, Kluwer Academic Publishers, 1998, pp507-515.
- [601] R. H. Weston, "Computational Infrastructures and Component-based Design in Support of Global Manufacture", Global Manufacturing Strategy Module - Course Notes, Loughborough University, 1999.
- [602] D. S. Linthicum, "Guide to Client/Server and Intranet Development", John Wiley and Sons, 1997.
- [603] CCTA, "Prince 2: Project Management Methodology", Central Computer and Telecommunications Agency, 1996.
- [604] J. Martin, "Rapid Application Development", Prentice-Hall, 1991.
- [605] SSA, "Basis: BPCS Client/Server Advanced Systems Implementation", System Software Associates, Frimley, UK, 1998.
- [606] A. D. Preece, "Expert Systems: Human Issues", Chapman and Hall, 1990.